Notre Dame University-Louaize
Faculty of Business Administration & Economics
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The Need and Importance of the Renewable Energy
as Perceived by Lebanon's Experts (The Case of Electricity)

Submitted by: Anthony Hany Keyrouz

Supervised by: Dr. Fakherdine Keyrouz

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The Need and Importance of the Renewable Energy as Perceived by Lebanon's Experts (The Case of Electricity)

BY

ANTHONY HANY KEYROUZ

GRADE: B-

Approved by

Supervisor's Name and Signature: Dr. Fakherdine Keyrouz Fakherdine

Reader's Name and Signature: Dr. Nicholas Bitar

Committee Chair Name and Signature: Dr. Roy Khoueiry

GRADUATE DIVISION
FACULTY OF BUSINESS ADMINISTRATION & ECONOMICS
LOUAIZE

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Date

DECLARATION

I hereby declare that this thesis is entirely my own work and that it has not been submitted as an exercise for a degree at any other University.

ANTHONY HANY KEYROUZ

ABSTRACT

Purpose: Exploring the perception of the Lebanese experts concerning the need and importance of the renewable energy in Lebanon, with a focus on the Lebanese electricity sector. It aims at assessing the extent to which renewable energy such as wind, solar and hydro power is needed in Lebanon and its impact on alleviating the existing electricity crisis in the country.

Design/methodology/approach: This study is an exploratory research. The secondary research was performed and the results are presented in two sections under the literature review chapter, describing several opinions and arguments concerning the social responsibility and the sustainability towards a green economy in the world and specifically in Lebanon. The primary research was performed using several semi-structured interviews conducted with Lebanese experts concerning the Lebanese electricity sector in addition to the feasibility of renewable energy implementation in Lebanon.

Findings: The main findings are that the renewable energy implementation has started slowly in Lebanon in addition to current and planned rehabilitation and maintenance for the Lebanese electricity sector. Furthermore, renewables are much needed in Lebanon since they constitute the permanent solution to the electricity crisis in the country.

Research limitations/implications: The sample of the semi-structured interviews is small and as a result the conclusions might be limited. As this is an exploratory research, it is not the outset to make conclusions based on statistical facts but it is the idea to make tentative conclusions that can be used to establish if any further research would be feasible.

Practical implications: The study focuses on the awareness, understanding and feasibility of the renewable energy sources taking into consideration the sustainability and the Lebanese social responsibility.

Originality/value: The conducted semi-structured interviews reflecting the current status of Lebanon regarding the progress and implementation of the renewable energy sources. Also, a new concept proposal for the currently considered far-fetched Solar Power Satellite.

Keywords: Renewable energy, electricity, sustainability, social responsibility, green economy, green electricity, greenhouse gas emissions, solar power satellite.

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CHAPTER 1

INTRODUCTION

1.1 General background

I quote the first introductory lines from Chu and Majumdar (2012) article; "*Access to clean, affordable and reliable energy has been a cornerstone of the world's increasing prosperity and economic growth since the beginning of the industrial revolution. Our use of energy in the twenty-first century must also be sustainable. Solar and water-based energy generation, and engineering of microbes to produce biofuels are a few examples of the alternatives*".

Since the beginning of time, man has evolved and constantly tried to evolve his standards of living. From the cavemen back then, arriving to our current times, human's efforts for a better life has always been a prime objective. Although the evolution is considered as a worthy achievement, severe universal issues that could threaten our existing life on our mother planet Earth, exist today in the 21st century. Environmental degradation, declining nutrition on sea and land from rising CO_2, swift decrease of fossil reservoir, and most importantly global warming, are the major issues caused by our seeking of a better life.

The developing countries' populations are increasing continuously because of the new living standards, therefore the demand for energy will also increase which makes it highly proportional to the population growth. In the year 2000, the world had 6.1 billion human inhabitants. A projection of the current number shows that "*it could rise to more than 9 billion in the next 50 years*" (United Nations, UN, 2004). The UN stated that "*this future population increase is mostly due to very rapid increase in less developed countries although the number in the more developed countries will be almost constant of about 1 billion or rather decrease*".

The consequences of the human population's prompt growth lie within a parallel increase in the consumption of energy, food, and material resources. Today, major power sources come from fossil fuels such as oil, coal and natural gas. Nevertheless, fossil fuels have two serious, yet severe factors preventing them from being used for the long term as a primary power

source. First, they are finite in supply (Cape Town. Electricity, 2013) meaning that their limited amount will not suffice the world demand in the future if they are used following today's needs. Second, they contribute heavily in the present global warming crisis with the greenhouse gas emissions they produce, naming carbon dioxide.

Pachauri and Reisinger (2007) stated that "*atmospheric CO_2 has increased from 275 parts per million (ppm) before the industrial era began, to 379 ppm*". Forecasts indicate that it could and will pass 550 ppm this century. This was in line with Thomson (2002) who stated that the current climate models and their relevant data indicate that 550 ppm, if sustained, could eventually produce a hazardous global warming.

1.2 Need and purpose of the study

Following the present global warming crisis, nations are looking to substitute their current energy sources causing pollution and greenhouse gas emissions. There are a handful of options considered for current energy replacement. Solar, wind, hydropower, biomass, geothermal, hydrogen, ocean thermal, tidal power etc., are considered today as main substitutes for traditional power sources. These energy sources are known as Renewables out of which solar power is the most promising one. Stine and Geyer (2001) stated that "*terrestrial solar power has too many limitations like atmospheric attenuation, daily and seasonal variation, and is affected by climate conditions*". This was in line with Wolfgang (2004) who indicated that the "regenerative" energies (solar, hydro, wind, etc.) are crucial and should be addressed seriously in the coming decades in order to limit the CO_2 expansion in the atmosphere. He added that this step is critical for climate stabilization.

The aforementioned problems can be mitigated with the renewable energy sources which are environmental friendly and don't run out with time. Also, the concept of Solar Power from Space is important and is defined by placing a gigantic solar power station in space orbiting around the earth. It absorbs the solar power and redirect it to Earth using microwave power transmission to a large antenna on earth. On Earth, the solar radiation is converted into electricity and renewable energy, hence substituting conventional power sources. This could be achieved by implementing Solar Power Satellites (SPS) that can provide a substitute for

electricity as we know it. They could capture the Sun's energy to be converted into Green Electricity on Earth. The environmental impact is diminutive compared to the current effects. Mankins (2012) clarified that *"space solar power can provide large quantities of energy to each and every person on Earth with very little environmental impact"*. Boechler et al. (2006) argued that the main goal is to use the "potential" of space in order to improve the green electricity production on earth, hence eradicate the problems of energy scarcity and the global warming concerns. They added that the SPS concept is becoming attractive for public support since being a "strategic asset" because of its capability to generate sustainable green energy. This was in line with Mankins (2001) who specified that the worldwide energy demand is growing radically consistent with worldwide environmental concerns, hence the need for power from space will also increase during the same time frame.

Green Electricity Marketplace (2013) defined Green Electricity as the electricity produced from sources that don't harm the environment. All of these sources don't run out with time, this is why they are known as renewable energy sources. Being environmental friendly, renewables are alternatives to conventional electricity generated from fossil fuels naming coal, oil and natural gas.

1.3 Brief overview of chapters

Chapter 2 reviews the literature of the social responsibility, the sustainability and the environmental impact of the current methods to obtain power / energy. Also, it covers the green economy relevant to the green electricity from renewable energy sources. Chapter 3 states the procedures and the methodology used, where Qualitative data is collected through semi-structured interviews conducted with experts concerned with the topic. Chapter 4 reveals the findings of the analysis, and presents an additional proposal in addition to the renewable energy sources; the Solar Power Satellite concept implementation that can be used in the near future. Finally, chapter 5 covers the conclusions and the recommendations of the thesis, and proposes future research involving new technologies.

CHAPTER 2

REVIEW OF LITERATURE

2.1 Introduction

The Sun is a colossal fusion reactor, usefully located around 150 million kilometers (km) from planet Earth. Its energy radiations constitute 2.3 billion times more than Earth's disk emissions. The latter is more energy in an hour than all human civilization directly uses in a straight full year. The truth being told; the sun will continue to yield free energy for billions of years to come as per NASA's Space Based Solar Power Group. Our Sun is the major acknowledged energy supply in the solar system. Just around the Earth's crust, every square meter of space receives 1.366 kilowatts of solar radiation. Ferrey (2006) discussed that "*solar energy is the source of all energy on earth, creating wind and water movement and ultimately creating plants, biomass, and animals, which become fossil fuels when their organic matter decays*".

2.2 Brief History of Renewable Energy

The renewable energy technologies started to get momentum in the 1970s, on the aftermath of the energy/oil crisis in 1973, as per Elliott (2003). Since then, renewables progressed and emerged into the world markets as a complimentary or backup energy sources side-to-side with fossil fuels. This involvement is expanding quickly, stirred by the constantly growing energy demand. Elliott confirmed this statement by noting that by the year 2000, renewables (traditional hydro and biomass) were providing 2% of the global energy or around 3% of the world's electricity.

In his paper entitled "The Future of Today's Energy Sources", Bulkin (2003) explained that in 1973, when the oil crisis stroke the world, people started to look for substitutes for the energy sources they deployed. In this context, some serious predictions were taken into account, which stated that the world's oil reserve would deplete by the year 2000. Thus, concentration on solar energy began to emerge. Nevertheless, at the same time, various experts warned that

"energy crises" occurred many times before, but still had rarely the consequences of their predicted outcomes.

The "British Petroleum" (BP) company conducted a study in 2004 entitled "Review World Energy Statistics 2004". The study found that the global world oil reserves will last for 41 more years, while the global natural gas will last for 67 more years. Following these forecasts, the oil reserves were expected to suffice until year 2045 while the natural gas will serve until year 2071.

The study added that the world's energy use is appropriately distributed into four main classifications: power generation, transport, agriculture/industry/domestic use, and conversion of one fuel to another. The most diversified class is the power generation encompassing oil, coal, nuclear, gas, and hydroelectric. The fact that nothing will hold the world demand for electricity cannot be denied. This is what is urging the renewables to grow at a rapid pace especially the solar and wind fields.

2.3 Growth, Economy and Business Aspect of Renewable Energy

Ferrey (2006) discussed that the "*human capture of this energy* [solar] *is not efficient; energy used by humans equals only about 0.01% of the total solar energy reaching the earth*". This was in line with Lovins et al. (2008) who stated that the potential of the wind's energy power accounts for 35 times of the global electricity use. They added that each 7 minutes, the solar energy yields enough power to supply all humankind during an entire year. This is because "*solar energy represents a constantly replenished flow.*" Regarding this statement, Ferrey (2006) confirmed that "t*omorrow, the earth will have exactly as much solar energy as it has today, regardless of how much solar energy is used and consumed each day. By contrast, burning a barrel of oil or a cubic meter of natural gas diminishes permanently that quantity of fossil fuels for the next day and for future generations*".

Speaking of the sun, Elliott (2003) described it as a "*working fusion reactor that already supplies more energy than human beings could use*", but technologies should be put in place so to capture its energy efficiently. He added that the solar energy has three main characteristics;

1- It affects the global climate
2- It supports the biomass growth
3- It generates waves, wind, and rain to sustain rivers' flow

Elliott (2003) also added that the moon's "gravitational pull" exerted on the sea results in what experts call the "tides lunar power". This energy source is not exactly a renewable one, but the consequence is the heat which is stored underground. This is formed through "radioactive decay" which is considered as a "geothermal" energy source.

Back to solar, Jackson (1992) affirmed that this energy equals 90,000 Terawatts from which around 1,000 Terawatts can be captured, converted, and used as a renewable energy source. The drawbacks for this process lie within the efficiency losses and constraints surrounding land usage, nevertheless a sufficient energy exists and could be deployed to meet the world's needs at least for several times.
The present and projected learning curves for solar and wind energies indicate that renewables are becoming more economically viable than ever. Although their costs are projected to decrease with time, the economic benefit of the solar and wind energies will be realized if and only if energy generation is integrated with renewables though transmission, distribution, and storage of electricity.

It is good to note that the wind and solar energy prices are decreasing each day; this is an example of an opportunity for countries that used to import energy, where now they can have energy production and therefore export it. Wood (2010) added that in order to meet the climate control goal, people need to transform the way they use energy by maximizing the efficiency and making a serious change toward carbon-free electric generation, "smart" transmission and distribution electricity systems, carbon-free emission automobiles, low-carbon "buildings", and finally alternative travel methods and land use.

Here are some of the renewable energy sources discussed in matters of cost:

1- Solar: these energy costs are influenced by reducing the production costs of the "solar cells" while increasing their efficiency. As said by Casey (2013), a European research team was able to accomplish a world record solar conversion efficiency achieving

44.7 percent in September 2013. Assuming that higher efficiency is translated into lower costs, it could and certainly will be the beginning of a long, sharp decline in the solar power cost. Experts have suggested that 50 percent cell efficiency could be achievable in three to five years.

2- Wind: these energy costs are influenced by the improvements of turbines and the increase of the wind towers' height, as per Bolinger and Wiser (2012).
3- "Decarbonizing" fossil-fuels emissions: these energy "costs" are influenced by reducing the carbon emissions. This can be done by reaching an advanced prime use of energy by the way of cost-effective enhancements in "thermodynamic" efficiency, productive use of wasted heat, etc.
4- Nuclear: these energy "costs" are influenced with the degree to which it can help decarbonizing the electricity production. Noting that the global nuclear energy production accounted for 14% of the full electricity generation in 2009, where it dropped to 12% in 2011.

Also in the renewables' context, the bio-energy is considered one of the most promising energy resources. Hence, bio-fuels have a major potential of generating bio-electricity. As per the "International Energy Agency" (IEA), the demand of bio-energy will grow at an annual average of 1.6% by the year 2030. This is because the developing countries will have high exponential growth in energy consumption. It will be incorporated in the two important sectors; electricity and transportation.

Da Silva (2011) et al. stated that both the environmental sustainability and the energy supply's security, urge the implementation of bio-energy because of its carbon free energy supply and its competitiveness comparing to the current renewables that exist today. They added that it is difficult to replace the fossil fuels because of their advanced extraction technologies and their economic viability, hence bio-energy will focus on the transportation sector where it is mostly needed. Discussing bio-energy should always consider the bio-mass which is contained in "waste" such as agricultural materials, sugar cane, forestry, etc. Also, bio-diesel is a "biodegradable" fuel which can be generated by processing vegetable oils or even animal fats. Da Silva (2011) et al. added that today, bio-diesel is being used in buses, boats, governmental automobiles, postal services and underground mining. Although it can be

used in various fields, not all the bio-diesel's developments appear to be positive because it has advantages and drawbacks at the same time, in contrast to bio-energy which is strongly beneficial for the environment. I quoted the environmental advantages and drawbacks of the bio-energy from Da Silva et al. (2011);

The environmental advantages of bio-energy:

- *Bio-energy is a renewable energy source and has great potential for economic growth*
- *Investments for bio-energy create far more jobs than the same amount of investment in conventional energy production*
- *Fuel from bio-mass has the facility to be stored and used when needed, even for a constant supply of electricity and heating*
- *Bio-mass can generate energy by using organic matter of vegetable or animal origin, including forest products such as saw-dust and bark and agricultural residuals such as straw and manure*
- *The combustion of bio-mass to generate bio-energy releases about the same amount of carbon dioxide than the burning of fossil fuels*
- *Pure bio-diesel extensively reduces greenhouse gas emissions. By combining it with diesel fuel, emissions may also be reduced, but in smaller proportions*
- *By using crops and animal waste, a new source of bioenergy would be available to its producers*
- *Bio-diesel and its derivatives, such as "phenol", are already being used to make plastics, adhesives and foam insulation. It is possible that, in the future, none of these products will be derived from petroleum or natural gas*
- *The production of bio-fuels with appropriate care and technology may sustain the environment*

The environmental disadvantages of bio-energy:

- *Bio-mass energy is less effective than fossil fuels. Therefore, difficulties arise from the large amount of material from vegetable bio-mass that must be made available to large power plants*
- *The production of bio-mass energy has externalities that are transferred directly to the consumer through taxes; however, since it is a source of cheap fuel, bio-fuel production is costly due to its ineffective production*

- *Bio-mass combustion also increases air pollution that varies according to the material and production method used*
- *The increase in the use of bio-fuels potentially reduces the area available for subsistence food crops and this would raise the price of food*
- *The cultivation of sugar cane to produce ethanol and sugar, despite the use of special techniques, increases soil erosion and pollutes aquifers*
- *The cultivation of crops for bio-energy production may require the high use of pesticides, fertilizers and water thus threatening the sustainability of the environment*

In the same context, Chu and Majumdar (2012) illustrated methods for producing fuels from different feedstock and/or products;

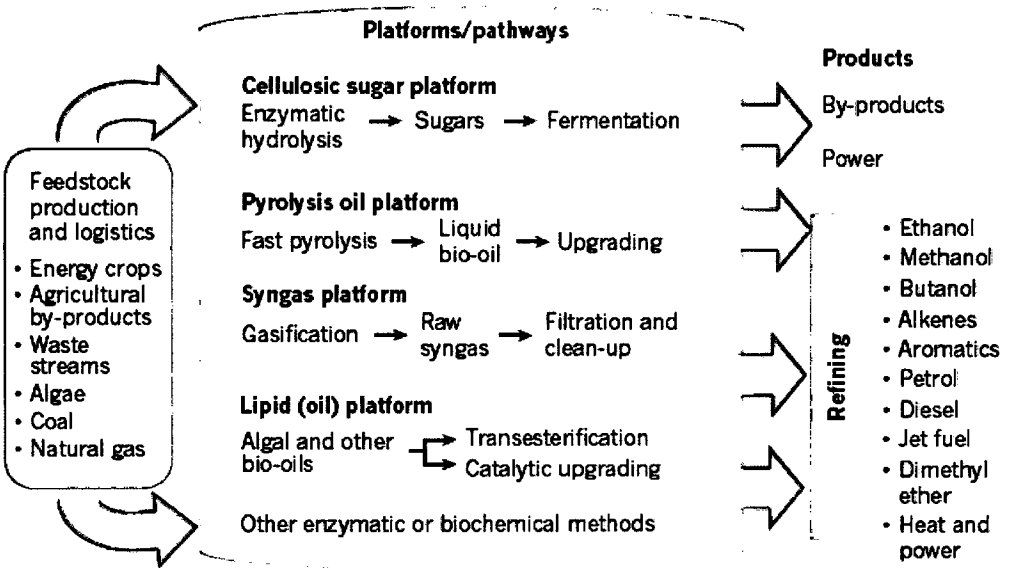

Figure 2-1 Producing fuels from various feedstock (Source: Chu and Majumdar, 2012)

2.4 Sustainable Development of both Energy and Environment

Najam et al. (2003) stated that in the early 1990s, the "United Nations Framework Convention on Climate Change" (UNFCCC), held a convention where most of the countries approved and signed a protocol aiming at protecting the global climate structure. Although they held different responsibilities towards the climate change, as well as different capabilities, all the

countries recognized the dangerous effect of the global warming as a result of the continued greenhouse gas emissions from fossil fuels burning. Hence, they unanimously agreed to limit these emissions. In the same context, the UNFCCC's parties decided that the developed countries should be the ones to "take the lead" in "fighting" the global climate change.

Furthermore, the U.S "Environmental Protection Agency" (EPA) declared that the CO_2 emissions hold the highest account for the global warming with a 79% of the total. The IPCC noted that the combustion of fossil fuels are a major part of these emissions with a 57% caused by man. The 2009 "Clean Air Act" revealed that the electricity generation is responsible for 34% of the global carbon emissions, while the transportation accounts for 28%. These two "gorillas" depend heavily upon fossil fuel combustion. Nevertheless, Davis (2008) highlighted on the Energy Information Administration's (EIA) 2008 report which indicated that the electricity sector possesses a higher cost-effective opportunity in reducing the CO_2 emissions compared to the transportation sector. Hence, the former will be focus in reducing the carbon emission in the first stages. Also, the "International Panel on Climate Change" which periodically assesses the "science" of the climate change and projects into the future, insisted that the worldwide carbon emissions should be reduced by an average of 80% and even more in order to control the temperature increase, hence stabilize it at 2°C or below.

Steven Ferrey introduced his 2011 paper "The New Climate" by stating that "*The Alphabet Starts with "C"; "C" is for "carbon," "climate," and "conundrum"*". This was to express the seriousness of the carbon emissions affecting the world climate, which is represented as a mystery to solve. Also, Rauch (2007) discussed the global warming as being the prime focus in the 21st century. He added that it is impossible to reverse the damage that has been inflicted by the greenhouse gas emissions. In the same context, James Hansen, a well-respected world climatologist and head of NASA's climate office, stated that the world has until year 2015 to reduce the emissions of carbon or face a totally altered planet.

In addition, Goldemberg (2007) confirmed that because of their devastating effect on the environment, in addition to various concerns about "depletion", fossil fuels should not be considered as the world's leading source of energy. This condition is strictly applied on the next two generations as a maximum period. Another drawback is the continuous increased

fuel prices due to the near future exhaustion in the reserves. Also, concerns for oil supply surrounding politically "unstable" countries (such as the Middle East) is a disadvantage, as per Lee et al. (2007).

Also, Lee at a. (2207) added that the aforementioned concerns must be addressed to conclude how a "sustainable energy system" should be. Four elements must be included:

1- Physical: as in securing enough energy supplies for future demand.
2- Environmental: as in bringing attention to the current energy sources leading to the global warming.
3- Geopolitical: as in conflicts and security risks surrounding the disproportionate distribution of the energy sources.
4- Equity: as in "access" to food and other resources provided by "modern civilization".

In the same context, as per the "Energy System Group of the International Institute for Applied Systems Analysis" (IIASA), the "Brundtland" report discussed a scenario with the current energy sources being used for a long term. The scenario resulted in four major disturbing events, naming:

1- The serious probability of climate change generated by the "greenhouse effect" of gases emitted to the atmosphere, the most important of which is carbon dioxide (CO_2) produced from the combustion of fossil fuels
2- Urban-industrial air pollution caused by atmospheric pollutants from the combustion of fossil fuels
3- Acidification of the environment from the same causes
4- The risks of nuclear reactor accidents, the problems of waste disposal and dismantling of reactors after their service life is over, and the dangers of proliferation associated with the use of nuclear energy

To alleviate these threats, Stern et al. (2007) stressed on the importance of "attaching a price" to the carbon emissions by stating that this strategy should be implemented. The lack of this condition has been described as the "*greatest of all market failures*". An example of attaching a price of $100 USD per ton of carbon emitted would go an extra mile in reducing the "deforestation of tropical forests", thus reducing the carbon emissions into the atmosphere.

Moreover, Elliott (2003) also established the fact that fossil fuels create environmental disasters. Above and beyond acid emissions, fossil fuels' combustion to generate power as well as automobiles' emissions, generate CO_2 which, in addition to other greenhouse gases such as "methane", are responsible for the global climate change that is already initiated. Nevertheless, there is a majority that agrees upon the fact that the global warming is not necessarily due to man's activities, or even that anyone can do anything to limit its expansion. Conversely, the IPCC released a study in 2001 which concluded that man's activities are in fact the major cause of the global warming, and if no actions are taken, the world will be ahead of various problems not only ecological, but also economic and social. Some of the climate change indications include intense storms, droughts and floods especially to "low lying areas" in the world, temperature rise, sea level rise, etc. Continuing, Elliott confirmed the fact that the developed countries have created the problem of global warming through industrialization, i.e. carbon emissions. He added that the least that these countries can do is to lead the way in finding alternatives to reduce the pace of carbon emissions and limit the dangers of global warming.

Nevertheless, the technological advances are improving in matters of finding and extracting fossil fuels. Hence, their cost is, and will always be competitive with the carbon-free energy sources for the years to come, especially because of the continuous growth in energy demand. However, if the world is to mitigate the climate risks accordingly, it needs to speed up the adoption of the carbon-free energy sources and technologies on a global scale. To accomplish this major task, governments need to imply policies in order to motivate the invention and/or innovation related to clean-energy solutions. Munich RE (2012) stated that the increase in the number of severe weather climate changes as in rise in temperature, floods, storms, wildfires, etc. over the past 30 years, have incurred losses exceeding 150 billion USD per year. The IPCC added that there is enough evidence showing that the climate changes have a high correlation with the aforementioned disasters. (IPCC, 2012)

In this context, Huq (2011) indicated that the richest 1 billion people are the ones that should be held responsible for the greenhouse gas emissions. Hence, to begin the shift with these people by making them change their "high consumption lifestyles" is not easy because it requires a serious behavioral transformation. This condition happens to be quite dubious, at

least in the short term. Also, another factor that could help make the shift could be some radical worldwide policies aiming at reducing the fossil fuel usage, but no government has proved its willingness in that matter so far. This is confirmed with the "history of sustainable development" which is exactly "the history of *un*sustainable development", with loads of broken promises. Therefore, focusing on the rest, which is the second and/or the third billion richest people could be the solution. Countries that are witnessing a fast development like Brazil, China, South Africa, and India could be the target. These countries might be the key holders to a fast transition. Satterthwaite (2009) stated that "*If they* (the aforementioned countries) *follow the path to lifestyles with diets high in meat, multiple cars, air conditioners, and flying across the world, and if their energy needs are met by investments (which are largely still to be made over the next decade or two) in fossil fuel systems, then we will be locked into a fossil-dependent future for a very long time, and that would mean any hopes of stabilizing stratospheric carbon would be doomed*".

Within the same setting, Huq and Ayers (2007) stressed on the "injustice" concerning the emissions topic by specifying that the poorest billion people divided within the poorest countries are only responsible for 5% of the total emissions. They stated that "*the rich have caused the problem, but the poor will suffer the consequences first and hardest*". These countries/people are the "victims" of the global warming but they can also be "change agents". In addition, their gesture in reducing their emissions could be an inspiration or an example to the rich or other countries.

Moreover, the "World Commission on Environment and Development" (WCED) defined the sustainable development as "*a development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two key concepts:*

- *The concept of "needs," in particular the essential needs of the world's poor, to which overriding priority should be given*
- *The idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs*".

For that matter, four key elements concerning sustainability have to be settled;

- *Sufficient growth of energy supplies to meet human needs (which means accommodating a minimum of 3 per cent per capita income growth in developing countries)*
- *Energy efficiency and conservation measures, such that waste of primary resources is minimized*
- *Public health, recognizing the problems of risks to safety inherent in energy resources*
- *Protection of the biosphere and prevention of more localized forms of pollution*

Furthermore, Watson et al. (2010) explained that the literature of sustainability includes three comprehensive components; eco-efficiency, eco-equity, and eco-effectiveness. This concept which was entitled as the "eco-goals", was elaborated by Dyllick and Hockerts in their 2002 paper.

1- Eco-efficiency: DeSimone et al. (1997) defined this perception as "*the delivery of competitively-priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life-cycle to a level at least in line with the earth's carrying capacity*". Suppliers are motivated by cost reductions. The latter can be provided through an eco-efficiency production, hence making it consistent with the corporate goals. The whole process can be described as an "economic pressure" affecting organizations and consumers. The former will engage in the eco-efficiency protocol in order to increase their profits, while the latter will react to the pressure in order to decrease their energy consumption. An example to highlight this formula is the hybrid cars' worldwide success. As a result, what is clear is that economics represents a key force in this change.

2- Eco-equity: Gray and Bebbington (2000) defined this view as an "*equity between peoples and generations and, in particular, the equal rights of all peoples to environmental resources*". The aim of eco-equity is to focus on the social responsibility towards the future generation. This is because the latter will be the one to endure the consequences of the current energy consumption methods concerning the limited or scare resources, leading to environmental degradation. Therefore, corporate and social norms need to be developed in a collective manner so to support

the eco-equity notion starting today and continuing into the future. For instance, governments or countries could promote the perception of a sustainable energy lifestyle such as the San Francisco's plastic shopping bag's ban. Consequently, both consumer and organizational behavior need to be addressed.

3- Eco-effectiveness: McDonough and Braungart (1998) were the first to define this concept. They indicated; "*Our concept of eco-effectiveness means working on the right things—on the right products and services and systems—instead of making the wrong things less bad*". This idea is similar in perception as the "difference between efficiency (doing things right) and effectiveness (doing the right things)". Eco-effectiveness is a fundamental solution to the ecological issues. It requires a change in the business models' design; from inception to implementation. Reducing the ecological destruction is the prime object; people should stop using the scarce non-renewable resources that have a devastating effect on the environment. McDonough and Braungart (2002) added; "*We need to direct individual and organizational attention to the underlying and fundamental factors of environmental problems and to make possible long-term prosperity and sustainability through a fundamental redesign of the economy. Business needs to adopt goals beyond efficiency, and it needs to also embrace sustainability, restoration, and regeneration as standard organizational aspirations*". This was in line with Anderson (1998) who proposed the "cradle-to-cradle" model depicting that the linear thinking should be transformed to "closed loop systems". Same as the eco-efficiency, organizations will increase their profits through eco-effectiveness. For instance, "Interface", a carpet manufacturer who used to sell carpets, shifted to leasing them, and then started recycling the old ones. Hence Interface's benefits increased by raising its market value and reinventing itself through eco-effectiveness. This behavior results in what experts call an "Economic Pressure". Therefore, Interface's competitors will surely try to "mimic" the new strategy. The whole concept is a win-win situation. On the other side, governments need also to alter their business models. For example, the Danish government has placed a 180% tax on gasoline cars and Zero on electric cars. This behavior will most probably change the decision-making of numerous car buyers. The new Danish taxation system was proposed so to support Shai Agassi's design of electric cars, as per Pogue (2009).

Brown (1991) also defined the sustainable society as a society satisfying its necessities without threatening the projections of the future generations. This was in line with Kibert (2008) who assured that "*humankind should think seven generations into the future when making decisions about the environment*". In addition, Herman Daly added that "*There is something fundamentally wrong in treating the earth as if it were a business in liquidation*". As for the organizational side, Savitz et al. (2006) described a sustainable corporation as "*one that creates profit for its shareholders while protecting the environment and improving the lives of those with whom it interacts*".

Jackson and Michaelis (2003) defined sustainable consumption as "t*he use of goods and services that respond to basic needs and bring a better quality of life, while minimizing the use of natural resources, toxic materials and emissions of waste and pollutants over the lifecycle, so as not to jeopardize the needs of future generations*". But now, the question that remains is how the world should promote the people's consumption in order to reach the environmental "goals". Societies and markets can modify goods/services from production, to infrastructure, arriving to the ultimate alteration of the consumers' behavior.

In another context, Farber (2012) stated an important fact in his paper "Sustainable Consumption, Energy Policy, and Individual Well-Being" which identified that the most of the environmental threats are in some way linked to the consumer behavior. The author stated that "*water is used to grow food for consumers or to water lawns; biodiversity is threatened by destruction of habitat for housing or agriculture; air and water pollutants come from automobiles, power generators, or factories that supply consumers with goods, energy, or services*". In addition to the development of the renewable energy sources, other alternatives can also be implemented to reduce the damaging effect of the energy use; i.e. sustainable consumption. These alternatives lie within decreasing the energy amount that is consumed. This technique can be effective and efficient at the same time. Farber (2012) included some of the "tips" that can be used for this purpose, naming;

1- *Higher-Efficiency Products*
2- *Improving Consumer Decision-making*
3- *Conserving Energy by Conserving Energy-Intensive Water Use*
4- *Improve consumers' diet and food systems*

5- *Motivating Consumption Changes: changes in consumer behavior have significant capacity to reduce energy use. The question is how to motivate these behavioral changes.*

For a sustainable consumption, consumers need to have effective labeling of products, which is called "green labeling". This shows the consumers the amount of energy and/or carbon included in the goods they buy. As per Farber (2012), sustainability is far more than just enterprises being regulated to minimize their carbons emissions. It is more into changing the way in which the world's businesses run, consequently, adjusting various facets of the everyday life. This adjustment should occur in two phases which in both, governments and/or policymakers play a crucial role; first, at the individual level concerning the decision-making related to green goods, second, at the societal level which provides people with a healthy environment to live in while decreasing the energy consumption.

2.5 Energy Efficiency and Electricity

In another framework, CERES, one of the leading non-governmental organizations (NGOs) submitted a report in 2010, in which it forecasted three crucial goals related to the energy to be applied in the near-future;

1- Reduce greenhouse gas emissions up to 80%.
2- Reduce dependence of fossil fuels to generate electricity.
3- Increase implementation of "smart grid" technologies aiming at "**Energy Efficiency**".

The "Lawrence Berkeley National Laboratory" affirmed that "*there is no universally accepted definition of energy efficiency. It is somewhat in the eye of the beholder. To engineers, efficiency describes the thermodynamic 'fit' between a task and the qualitative and quantitative energy needed to perform that task. An economic perspective would trade off costs and services received from efficiency. To some environmentalists, energy efficiency is the reduction of certain higher-pollution sources of electric production without much regard for the marginal cost of electricity. Some define energy efficiency as using less energy to provide the same service*". Achieving efficiency is based first on governments that should be implying standards and norms concerning energy use, second on the market-driven choices

made by consumers while paying the alternative price of substituting their current use of energy.

To confirm that price of energy is major characteristic for people, Heslop et al. (1981) conducted a research in the early 1980s to study the "consciousness" in the behavior of energy conservation. The research was conducted during a period of 6 years, and stressed on the electricity consumption to discern the different behaviors. A questionnaire was distributed so to collect the relevant data for the analysis. The aim was to highlight the significance of the "household characteristics" in addition to the size of the families on the electricity consumption's prediction. **Among the variables studied, only one appeared relevant to the energy use; the price consciousness. The social responsibility and the environmental consciousness were not significantly related to the energy use.**

In the electricity context, Beaver (2013) discussed the 1943's project of Leo Szilard, a physicist who suggested building a nuclear reactor that breeds fuel, delivering an unlimited amount of energy. The project was so convincing that governments started adopting the concept which would generate electricity through breeder reactors. This perception was appealing because in contrast to the renewable energy sources, the reactors were independent from sun and wind. Nevertheless, the goal has proved indefinable notwithstanding decades of research, development and billions of dollars spent.

In the same framework, Ferrey (2010) described the electricity as a "*signature technology of the modern era*" since it appeared during the last century. He added that "*electricity, unlike all other forms of energy, cannot be efficiently stored for more than a second before it is lost as waste heat. Therefore, the supply of electricity must match the demand for electricity over the centralized utility grid of a nation on an instantaneous basis, or else the electric system shuts down or expensive equipment is damaged*". This was in line with Brown et al. (1991) who stated earlier that factories and organizations will be able to save money and therefore increase the energy efficiency with both usable power and heat generation. Casten (2009) confirmed this theory by stating an example of an industry that captures the wasted heat prior of its exit of the stack, and then coverts it into electric power. By following this procedure, power could be created and brought back to be fed into the grid. As a result, sustainable

efficiency and costs saving can be both attained. This concept can be referred to as "doing more with less".

Chu and Majumdar (2012) stated that "*the Stone Age did not end because we ran out of stones; we transitioned to better solutions. The same opportunity lies before us with energy efficiency and clean energy*". This notion is important because it shows how much the people can have a positive effect on their future, in terms of energy efficiency and climate changes. Plus, the renewable energy's cost is getting more competitive and economically viable compared to other energy sources. Accelerating the transition toward an affordable sustainable energy results in powering the economic growth, increasing the energy security and mitigating the threats of climate changes. This was in line with the "World Energy Outlook" conducted by EIA, who confirmed that "*if we don't change direction soon, we'll end up where we're heading*".

The sustainable energy growth is always an optimistic topic. "Shell International" (1995) forecasted that by the year 2060, the renewable energy sources could meet around 50% of the world's overall energy demand. This was in line with the "World Energy Council" (1995) who also predicted that by the year 2100, renewables could meet up to 80% of the total energy demand, if and only if these are considered as a priority to complement the conventional methods while focusing on protecting the environment. However, the aforesaid assumptions are only theories, what the world needs is serious progress that can be seen through advancements in technologies and economic viability of the renewables.

2.6 Green Economy

It is now known that the forecasted scarcity of the fossil fuels and minerals is the essential driver for novice policies to engage in new technological efforts for a better future. As a result, the private sector has already made plans for low-carbon productions. Bigg (2011) stated that "*the economics of scarcity and uncertainty are stimulating significant efforts to develop alternative "greener" business models and patterns*".

Huq (2011) described the shift to renewables by stating the fact that this is an opportunity; "From Burden to Opportunity". What he meant is that to get carbon-free energy sources or energy mix, everyone should pay more, but only in the short term. Nonetheless, the advantage is that this transition is loaded with future opportunities starting with the "Green Economy". All of this comes with a certain risk, but risk is always a major motivator to gain more.

The concept of a green economy is based on avoiding hazardous global climate change, hence follow the notion of the "sustainable development". Therefore, in order to start with the shift, the world needs to transform the global energy mix used today from being totally dependent on fossil fuels to a "portfolio" of different energy sources that altogether have less carbon (if not zero) emission. The "deadline" for this change is the year 2050, but until then, people should start with the implementation as of today.

As per Bigg (2011), the green economy is about the possibility of achieving a sustainable environment, a social justice, and a steady economy in the long term through the organization of the people's lives and economies. It is an economy capable of producing a collection of benefits, naming environmental, social and economic, for a society, community and individuals specifically. In other words, green economy is the idea of an "environmental governance" with the role of restoring and protecting the ecosystems while preserving their biodiversity, in order to provide a security of the services that they deliver. Also, it suggests the sustainability in using the natural resources as a prime objective.

Najam et al. (2007) defined green economy as a major restructuring of the idea upon which a traditional economy is based. Najam and Halle (2010) added that "strong accountability mechanisms" should be induced from the very beginning in order to build the green economy since it is not just a matter of a renovation of the original economy with "green trimming". Nevertheless, what is meant is not a total disconnection of the current economy, but merely a restructuring that leads to an economic growth involving employment opportunities creation, as per Halle and Melendez-Ortiz (2007). Najam et al. (2007) indicated that deploying a green economy "*must lead us away from wasteful use of the earth's resources and ecosystems, from the depletion of species, and from air and water pollution toward clean, renewable, and sustainable forms of resource use*". Generation of wealth, efficiency and effectiveness would

also be present in the new economy, but what the world needs is to have them incorporated in the environmental and social side of the equivalence.

As per Halle (2011), there are a handful of fluctuating opinions on which of the social, environmental or economic factor should be given more attention. But, everyone agrees that the current economy has collapsed (and will always do) in a certain way since it focused on one and overlooked the other two factors. It is the people's economic behavior that will dictate the success of the "social marginalization" and the "environmental degradations" problems. This is because these two factors are essential in building a green economic organization. In other words, the factors motivating the personal behavior or the consumer choice should be aligned with the requirements/needs of the green economy.

In addition, Halle expressed the green economy importance by stating an example; "*unless we do so* (switch to green economy), *the likelihood is that we will all, similar to victims of an earthquake, straggle back to our ruined houses only to rebuild them on the traditional design, with the same materials as before because this is what we know, this is what we are familiar with, even if we would be happy to sample new ideas if they were genuinely offered*". He added that accountability actions must be taken to guarantee that politicians cooperate with deploying the green economy and not only shout it from the rooftops in order to gain popularity while restoring the ruins of the traditional economy. What is needed is less broken promises and more serious actions toward the green economy, hence a high price must be paid for those who do nothing but throw theories. Prices could be in a financial form or not as to fasten the transition.

Wapner (2011) defined green economy as the "fair" usage of the earth's ecological wealth. He explained that such an economy can be attained when involving components such as:

1- "Full-Cost Pricing": Include costs of environmental degradation into the costs of goods/services (with rewarding the poor)
2- "Waste = Food": Make use of the consumers' waste as biological and industrial inputs
3- "Sustainable Ethics": Aim at a global awareness concerning the scarcity of the ecological resources while inspiring the consumption and production of products that are "ecologically sustainable"

4- "Progressive Green Taxes": Imply taxes on non-green consumption
5- "Wealth = Environmental Health": Preserving the nature is a wealth, having the consequence of health

In addition to the aforementioned components, a green economy should include environmental and social justice. This is because economies are driven by supply and demand, while ignoring the ecological and justice problems. Wapner (2011) added that "*building a green economy rests on embedding the global financial system within a broader socio-ecological frame of reference and practice*". It is important to highlight the fact that "economic prosperity" and consequently wealth, will mean nothing (or Zero) if health, livelihood and well-being of people are not maintained. If people continue to exhaust fossil fuels at the same rate of today, there will be no one left on the planet to enjoy his riches. This was in line with Elliott (1997), who stated earlier that the fuel prices are subject to political issues, in addition, the fuel reserves will deplete soon. These facts should not be the prime concern, in contrast, what people need to concentrate on is how to use safely what's left of these reserves, and therefore not harm the environment.

In the Business section, Cronin et al. (2011) pointed out that when organizations implement green strategies, they benefit by saving costs when they reduce their waste effectively. Innovation for products and/or services is needed when deploying a green strategy, where Woolverton and Dimitri (2010) argued that "*Businesses are in a unique position: by adopting practices that, when compared to standard practices, are better for the environment or other social aspects, firms can effect change by reducing the environmental impact of their actions, as well as setting an example for other businesses. As long as some consumers are willing to pay higher prices to support green businesses and products, higher costs are likely to be offset. As the global environmental crisis worsens, the number of consumers willing to support verified green products may well increase. However, economic conditions can easily temper this movement*".

Song-Turner (2008) also suggested that the result of firms taking on the green initiative, is the sustainability of the world's green economy. She added that a "global economic revival" can be attained though green businesses adopted by firms. In the same context, Saxena and

Khandelwal (2010) claimed that green marketing is major key into a profitable effort for a sustainable green economic growth. This is in line with the fact that green marketing is getting momentum each day because of the worldwide green awareness. They added that "*the adoption of a green marketing orientation by a firm is principally a response to the increased pressures by society for business to meet its comprehensive ethical and moral responsibilities.* [...] *Sustainability has constructed a bridge between business and green. The companies practicing the philosophy of green marketing will gain competitive advantage and sustainable consumption in the market place; and will enjoy sustainable development through green marketing*". Moreover, Ottman et al. (2006) posited that green marketing should satisfy enhanced environmental worth in addition to customer satisfaction. They added that for such marketing to be effective, it must apply decent values to make the green products "desirable" for consumers.

2.7 Social Responsibility towards a Green Environment

In the consumption framework, McDonald et al. (2012) conducted a research that studied the "Individual Strategies for Sustainable Consumption". Through a survey, they found that there are three strategies concerning the "Greening Consumption", naming:

1- The "Translators": consumers that have "green" and "grey" characteristics at the same time. In other words, they do not consider sustainability as their prime objective, and especially are not interested in any of its related political agendas. The translators' view towards greening consumption is their perception of doing the right thing. Although they do not seek it intentionally, translators have an open mind regarding any change.

2- The "Exceptors": consumers that consider sustainability as a priority in any part of their lives. They understand its meaning and engage in a certain lifestyle that is strived by a "*personal philosophy of consumption*". Exceptors are always seeking change, and are willing to make sacrifices for the sake of safeguarding the nature, consequently protecting the planet for the upcoming generations. These consumers are quite comfortable with substituting products as long as it complies with sustainability, and naturally, they tend to seek out other Exceptors.

3- The "Selectors": consumers that act as "green" in one part of their lives, nevertheless act completely "grey" in all other aspects; they tend to select a certain sustainable consumption and focus on it solely. These consumers represent the largest portion of the population. Selectors are motivated or attracted by a particular subject but are not interested in sustainability as an overall.

2.8 The Lebanese Case – Electricity

2.8.1 Introduction

Sustained actions are immediately required for the highly emitting countries of greenhouse gases, leading to climate change. The latter is a serious, yet severe worldwide challenge that could and will harm planet Earth unless rectifying actions are taken. For this matter, the Lebanese Government have set the target of 12% of total energy supply to come from renewable energy sources by the year 2020. This decision came through a Ministerial Declaration after the Ministry of Energy and Water's (MoEW) (Bassil, 2010) "Policy Paper for the Electricity Sector" publication in June 2010. This initiative is a result of Lebanon's commitment to the importance of finding solutions for the electricity sector. Also, it aims at finding new ways and opportunities in order to fight the threats that the climate change will likely to cause.

2.8.1.1 The Electricity Sector

In 2011, the MoEW described that the Lebanese electricity sector is in the middle of a severe crisis. It stated that "*the sector is unable to supply the reliable electricity needed by homes, offices and industries. It is a massive drain on government finances, crowding out more valuable expenditures on education, infrastructure, social protection, and health, and putting macroeconomic stability at risk. The state of the sector has reached a critical stage, with a massive drain on public resources (estimated at 4% of GDP for 2007 and 4.3% of GDP in 2009), significant revenue loss for industry and commerce, and exorbitant spending on back-up generation by the general population*".

In Lebanon, the electricity is supplied through Electricité du Liban (EDL). The latter is an independent public-sector entity that operates under the authority of the MoEW. EDL is responsible for the generation, transmission, and distribution of electrical energy in Lebanon.

The 2004's "International Energy Outlook" described that Lebanon is classified among the countries that provides a high electricity coverage compared to other countries in the region. The EIA's 2004 report stated that in 2002, Lebanon's access to electricity grew to be 96% (IEA, 2004) where in 2005, it reached 99.9% (IEA, 2006).
The Lebanese numbers for electricity demand are challenging for they cannot be easily estimated due to the fact that total production of the current power plants does not meet the actual real demand. This urges for imports and self-generation to try and bridge the gap or compensate for the shortage. Estimations of a 33% of the total electricity demand is met through self-generation, as per the World Bank (2008).

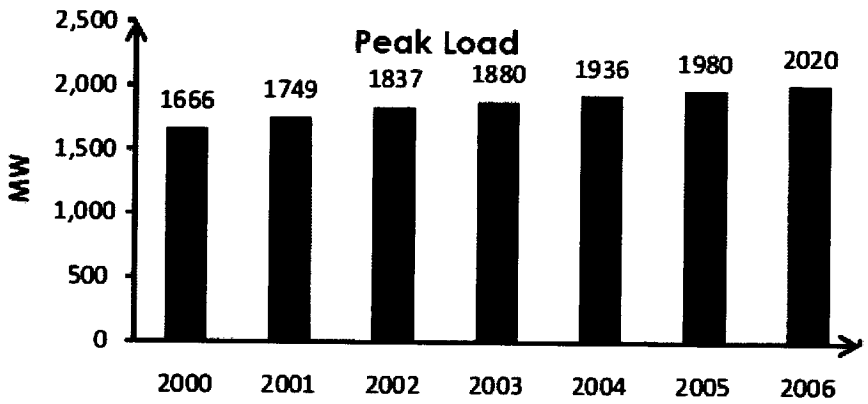

Figure 2-2 Electric Peak Load (Source: OAPEC, 2001-2007)

In Lebanon, the peak electric load increased from 1,666 Megawatts in 2000 to 1,936 Megawatts in 2004 (Figure 2-2). In 2009, the average demand was a little over 2,000 Megawatts as per the MoEW. Nevertheless, these numbers do not include the 33% self-generation, which when taken into account, the adjusted figures display a load of 2,215 Megawatts and 2,575 Megawatts in years 2000 and 2004 respectively. Figure 2-2 shows the Electric Peak loads between years 2000 and 2006.

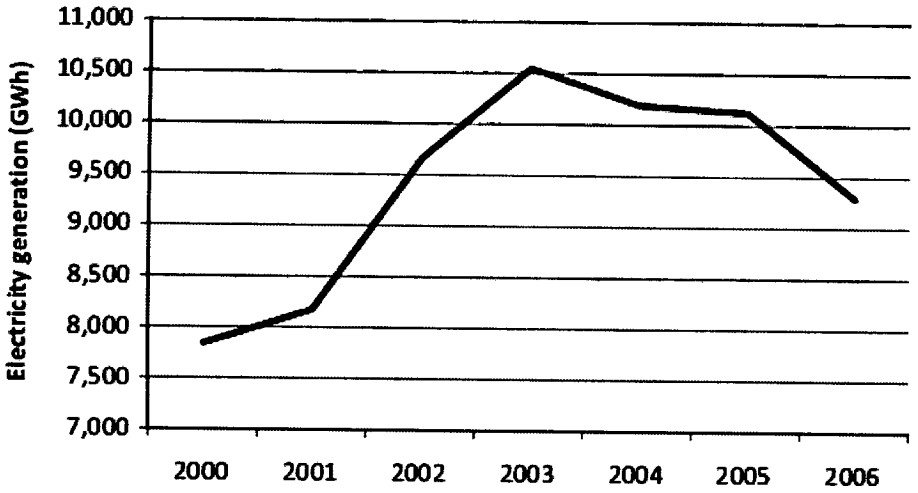

Figure 2-3 Electricity generation from 2000 to 2006 (Source: EDL, 2000 to 2009)

EDL's supply for electricity demand increased from 7,839 Gigawatt-hours in year 2000 to 10,191 Gigawatt-hours in year 2004. This increase accounts for around 30% in the aforementioned period. EDL's electricity generation trend between years 2000 and 2006 is shown in Figure 2-3.

MoE stressed on an important note which is the fact that EDL's decreased supply in 2006 is partly due to the damage of the electricity groundwork caused by Israel during the July-August 2006 war.

Seven power plants and five hydropower plants are Lebanon's main electricity production facilities, operated by EDL, the state's electric utility (Table 2-1 and Table 2-2). The available thermal power plant capacity accounts for around 70 to 80% of the initial installed capacity because many of the existing power plants operate below their optimal efficiency. This is an important point in the Bassil's 2010 electricity initiative which states that the current power generation must be increased, and for that matter rehabilitations and new plants constructions have already started; such as the Zouk plant. In addition, the total Lebanese hydropower capacity currently accounts for 274 Megawatts, with an actual generation capacity of 190 Megawatts, as per the MoEW and the United Nations Development Program (UNDP). Hydropower is essentially generated from three plants mounted on Qaraoun Lake with three turbines having a capacity of 34, 108 and 48 Megawatts respectively. Whereas Bared and

Nahr Ibrahim plants' capacity account for 17 and 33 Megawatts respectively. Altogether, the hydropower units in the abovementioned plants are between 40 and 70 years old, however they are not expected to be discharged in the near term since their rehabilitation is also included in the Bassil's 2010 action plan.

Unit Name	Total installed capacity (MW)	Available capacity (MW)	Efficiency (%)
Zouk	607	520	38
Jiyeh	346	295	33
Tyre	70	70	38
Baalbeck	70	70	38
Zahrani	435	435	48
Deir-Ammar (Baddawi)	435	435	48
Hreisheh	75	N/A	N/A
Total thermal capacity	**2,038**	**1,770**	

Table 2-1 Total capacities and efficiency of thermal power plants in Lebanon (Source: EDL, 2009 and World Bank, 2008).

Unit Name	Installed capacity (MW)	Capacity factor (%)	Annual energy (GWh)
Litani	190	47	775
Al Bared	17	34	50
Safa	13	22	25
Nahr Ibrahim	33	35	100
Qadisha	21	41	75
Total capacity	**274**	**43**	**1,025**

Table 2-2 Hydro power energy in Lebanon (Source: EDL, 2009 and World Bank, 2008).

Lebanon's supply of electricity in under the thermal capacity, which is divided into three main components:

1- Heavy Fuel Oil-fired steam turbines at Zouk, Jiyeh and Hreysheh
2- Diesel-fired Combined Cycle Gas Turbine (CCGT) at Beddawi and Zahrani
3- Diesel-fired Open Cycle Gas Turbine (OCGT) at Tyre and Baalbeck.

The Beddawi plant started operating on natural gas from Egypt as of October 2009. This shift aims at reducing the demand for gas oil, as per the Ministry of Finance (MoF, 2010).

In the late 1990s, and particularly 1996, Lebanon witnessed no expansions in its existing power plants, hence, no new power generation capacity has been added since. The resulting shortage has created lacks in supply which acquired back-up arrangements. Therefore, substantial investments by low-voltage consumers (households and commerce) and industry were made.

The power shortage is created due to the inability of EDL to meet the demand effectively. The latter is due to the insufficient generation capacity, high levels of electricity losses and load mismanagement. The World Bank (2008) confirmed that 33% of total electricity demand in years 2003 and 2004 was matched through the self-generation process where suppressed demand accounted around 8.8%. Figure 2-4 shows the consumption figures for the year 2006. The World Bank added that the self-generation increased between the years 1998 and 2006, hence inflating the consumers' electricity bills amounts by up to 25% so to satisfy the "security of supply" condition.

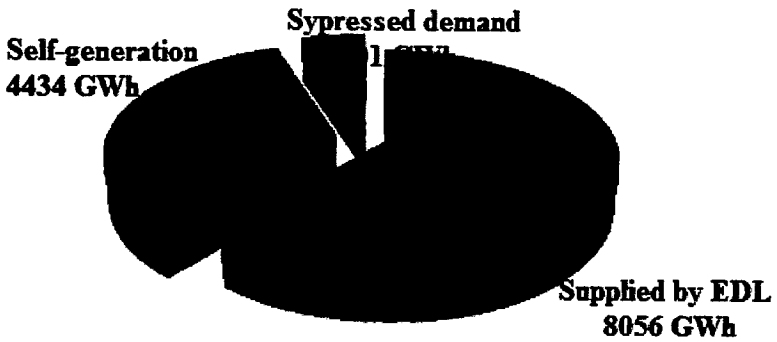

Figure 2-4 Estimated total consumption of electricity in 2006

For over a decade, electricity has been imported from Syria. In 2009, Lebanon also started to bring in electricity from Egypt, in order to try and bridge the production gap. Byblos Bank (2010) stated that since 1998, more than 8,000 Megawatt-hours have been imported from Syria based on its availability or surplus of power. Table 2-3 displays the annual import numbers between years 2000 and 2009. The World Bank added that in 2006, Lebanon imported a number close to 200 Megawatts at approximately 12 US¢/kWh (12 USD cents or USC per Kilowatt-hour), a number that is cheaper than the cost of electricity generated in our country.

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Imports (GWh)	1,397	1,263	532	-	216	455	929	972	561	1,116*

***589 GWh from Syria and 527 GWh from Egypt.**

Table 2-3 Electricity Imports from Syria throughout the years (Source EDL, 2000 to 2009)

The abovementioned EDL's electricity supply shortage is a result of two factors; technical losses in the network and thefts (which are also called non-technical losses). The technical losses account for approximately 15% whereas the non-technical losses, which are defined as the non-billed consumption of electricity through illegal connections on the distribution network, account for around 18%. The latter number (18%) is interpreted as a 150 million USD in incurred losses for EDL each year. This is not only due to the billing system's weakness within EDL, but also to the "political interference" regarding the electricity operations utilities.

To try and eradicate the problem, EDL has pursued a plan to reduce its non-technical losses over the past few years. As a result, a 3% decrease was achieved during the years 2004 and 2005. The World Bank (2008) stated that over 30% of produced electricity in Lebanon is not billed.

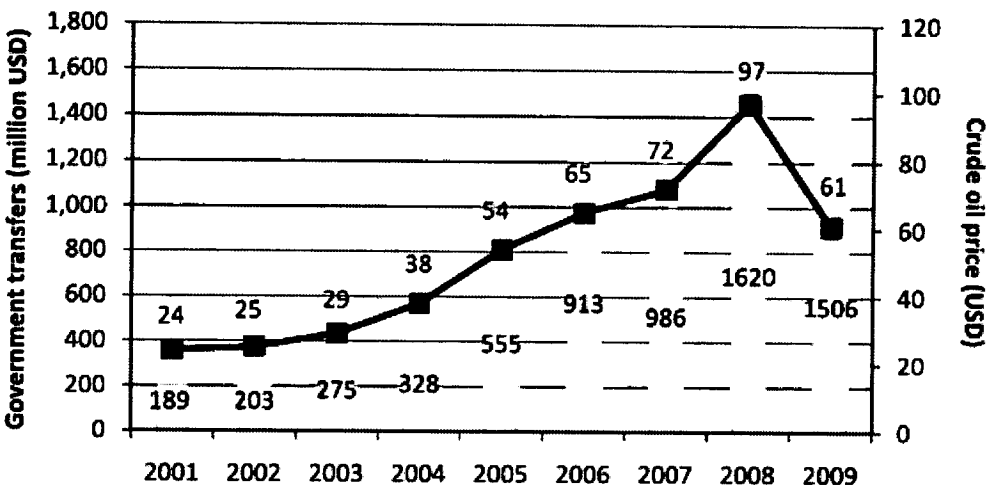

Figure 2-5 Transfers to EDL and crude oil prices (2001-2009) (Source: MoF, 2010)

The World Bank (2008) also stated that in addition to the power supply shortages, the electricity sector is costing the Lebanese government massive amounts of money with the generalized subsidies deployed to cover the oil bills. The Bank added that "*these low levels of*

revenues are caused by the tariffs being set far below cost recovery (as well as an inefficient tariff structure), as well as low billings and collections. With the huge increases in international oil prices in recent years, the lack of tariff adjustment since 1996 (when the oil price was USD 21/barrel) has become a clear and present cause of the fiscal drain of the sector".

Additionally, Lebanon did not benefit from the nearby regions' abundance in natural, however, it continues to employ the gas-oil or diesel in some major power plants initially designed to deploy natural gas, in addition to gas turbines designed as peaking plants. This was until the end of year 2009 which witnessed the arrival of natural gas from Egypt through Jordan and Syria. But still, the production costs were high due to the increased operations and maintenance costs of the power plants. These costs are the result of the inadequate ordered maintenance, shortage in machines' spare parts, and amplified technical losses. Although the electricity tariffs are below EDL's production costs which are leading to massive losses, any future tariff increase will most probably trigger the consumers to protest and hence, decline to pay the bills, as per the World Bank.

Because of the deficit, each year, the Lebanese government transfers money to EDL to try and bridge parts of the losses gap. These transfers are in the form of repayment of fuel oil and gas oil bills. However those same transfers should rather be invested in other activities yielding profits that could be used to compensate the losses instead of paying them from the treasury. The Ministry of Finance (MoF) (2010) stated that the substantial increase in the recent years reflects the high increase in the international oil prices, together with the constantly growing demand for oil. In Lebanon, in the year 2008, government transfers to EDL reached 1.6 billion USD while in year 2011, 1.57 billion USD were transferred from the state treasury to EDL, out of which 93% was allocated to purchase oil. This number equals to a rough 400 USD per person per year. MoF added that these transfers to EDL account as the third largest public expenditure element, (directly after interest payments and personnel cost respectively) which as per the World Bank, "*is putting macroeconomic stability at risk*".

2.8.2 Lebanon's commitment

Lebanon's "Second National Communication" (SNC) affirms once again that Lebanon's greenhouse gas emissions are negligible, hence trivial comparing to the global level. However, in order to contribute to a sustainable development and thus qualify Lebanon get involved in mitigating the climate change, the Lebanese government and particularly the Ministry of Energy and Water, have set a number of prioritized measures to reduce the greenhouse gas emissions, cut the energy demand and increase the energy supply. The Ministry of Environment (MoE) believes that "*combating climate change is a shared responsibility that rests on all our shoulders. It is more important to find a common solution than to debate the relative responsibility of each of us*". Consequently, this is the reason that strived Lebanon to voluntarily commit to increase its renewable energy mix to 12% by 2020 in the Copenhagen convention in year 2009.

Lebanon is affected by the global climate change, and the impact is remarkable. Not only temperatures are projected to increase between 1°C (Celsius) and 5°C from now till the end of the century, but also rainfall is projected to decrease by 25 to 50% over the same period. Consequently, these severe changes in climate will additionally worsen the current existing environmental, economic and social challenges that Lebanon is facing today.

2.8.2.1 Greenhouse Gas Mitigation Strategy

The scenario for the energy baseline is based on the MoEW's 2010 Energy policy paper (Bassil). Naming the most important points:

- Increase the installed capacity to 4,000 Megawatts by the year 2014 and 5,000 Megawatts subsequently to satisfy the forecasted demand based on a calculated annual load growth of 7%, and 15% of peak load reserve
- Rent or import 250 Megawatts barges or small generators between years 2010 and 2013
- Base 2/3rd of the fuel mix on natural gas provided by multiple supply sources
- Supply 12% of the fuel mix in the form of renewable energy sources by the year 2020

Two mitigation scenarios for reducing greenhouse gas emissions have been established. The first scenario involves the implementation of the MoEW's 2010 electricity policy paper, as well as reaching capacity expansions of up to 3,500 Megawatts between the years 2015 and

2030 based on natural gas. The second mitigation scenario also involves the implementation of the MoEW's 2010 electricity policy paper in addition to a full switch of the existing oil-fired power plants to natural gas by the year 2030, an increased penetration of renewable energy technologies' rate to up to 17% by the same year, and finally assure that no electricity is to be imported.

2.8.3 Bioenergy in Lebanon

The Lebanese territory possesses a reasonably abundant availability of "bioenergy" resources (bioenergy is yielding renewable energy produced by living organisms). This is because approximately one third ($1/3^{rd}$) of the Lebanese land is suitable for growing crops, having the most fertile regions located along the coastal strip and within the Bekaa valley. The "National Bioenergy Strategy for Lebanon" executed by UNDP under CEDRO project (Country Energy efficiency and renewable energy Demonstration project for the Recovery of Lebanon) contributes conclusively to the Lebanese government's goal of yielding a 12% of the country's total energy needs from renewable energy sources by the year 2020.

Assessment of the biomass resource in Lebanon (biomass is any organic matter used as a fuel):

Biomass sources that have the potential of producing power have been identified and were grouped following their origin;

a- Forestry
b- Wood and paper industries
c- Agriculture
d- Energy crops
e- Food processing industry
f- Municipal solid waste and non-hazardous industrial waste

Accordingly, the ten most promising bioenergy flows are;

1- Residues from forestry felling
2- Residues from fruit and olive trees
3- Residues from cereals

4- Energy crops on currently unused land
5- Olive cake by-products
6- Waste wood
7- Municipal sewage sludge
8- Animal fat and slaughterhouse residues
9- Yellow grease
10- Landfill gas recovery (specifically Naameh landfill)

The solid waste management to be used as feedstock is under the "Waste-to-Energy" plans. This concept has also a large potential, however it is not mentioned in UNDP's "National Bioenergy Strategy for Lebanon" plan since it will executed under the Waste-to-Energy (WTE). Bassil's 2010 action plan includes up to four WTE sites in Lebanon, naming Beirut, Tripoli, Tyr and Baalbek.

Lebanon's conversion options for bioenergy:
Various technology options exist for the conversion of biomass streams of interest in Lebanon into power, heat and liquid fuels. Twenty (20) conversion technologies have been selected and studied in UNDP's "National Bioenergy Strategy for Lebanon", naming;

A- Mature technologies:
  a- Liquid fuels production
    1- Vegetable oil biodiesel: alternative to fossil diesel fuel, made from plant oils
    2- First generation bioethanol: alternative to fossil gasoline, made from agricultural crops
    3- Animal fat and recycled oil biodiesel: alternative to fossil diesel fuel, made from waste fats and oils
    4- Fischer Tropsch biodiesel: feedstock gasified into syngas then condensed into a diesel replacement
  b- Biogas production
    5- Anaerobic co-digestion (manure and agro residues): feedstock is converted by bacteria into biogas
    6- Anaerobic digestion of sewage sludge: sewage sludge is converted into biogas by bacteria

7- Slaughterhouse waste biogas: slaughterhouse waste is sterilized, then converted into biogas by bacteria
8- Landfill gas: biogas is released by landfills, which can be collected and purified for fuel usage

c- Direct combustion
9- Waste to energy: WTE is the process of creating energy by combusting waste
10- Combustion combined heat and power: simultaneous generation of useful bioenergy
11- Combustion boiler: converts biomass into heat
12- Co-combustion of biomass and coal: partial substitution of coal by biomass in coal fired power plant

d- Pretreatment
13- Pelletization: drying and pressing biomass under high pressure into pellets with an improved energy density
14- Torrefaction: heating at atmospheric pressure in the absence of oxygen to improve energy density
15- Gasification-CHP: thermal conversion of solid fuel into a combustible gas under oxygen limitation
16- Pyrolysis: direct thermal decomposition of biomass into gas, bio-oil and char

e- Promising technologies
17- Algae options (centered in biodiesel): simple organisms that use sunlight to grow and produce oil (or other products)
18- Salicornia biodiesel: salicornia as a salt tolerant plant that produces oil
19- Lignocellulosic ethanol: woody biomass, grasses, or the non-edible parts of plants are broken down into ethanol
20- Fuel from MSW: using waste to produce a high quality biofuel

As per UNDP - CEDRO (2012), the feedstock resources can be combined over time in order to secure a long-term feedstock supply and fix the feedstock prices. Therefore, bioenergy plants can be constructed starting today, depending on the existing and/or available feedstock, couples with the establishment of various new energy plantations and feedstock collection systems. This process aims at making sure that there will be enough feedstock to keep up with

the bioenergy industry growth in Lebanon. It is important to note that the most applicable technologies for Lebanon involve liquid fuels production and direct combustion of biomass. The goal is to produce power and heat.

B- Liquid fuels production:

In Lebanon, the feedstock used for liquid fuels production is acquired from various sources. Nevertheless, numerous commercial options could create competition with food which basically contributes to rising the feedstock prices. Hence, it is imperative to explore more advanced technologies such as "Fischer-Tropsch biofuel and lignocellulosic ethanol" which deploys non-food feedstock and actually can employ a certain diversity of residues (*The Fischer–Tropsch process is a collection of chemical reactions that converts a mixture of carbon monoxide and hydrogen into liquid hydrocarbons* [Wikipedia 2014]).

C- Direct combustion of solid biomass:

There are several technologies that can be used for direct combustion of solid biomass in order to produce power and heat. Production units can range from 4 Kilowatts (household level) to up to 50 Megawatts (in the case of co-combustion). Also, combustion of Waste-to-Energy could solve waste disposal problems. Hence, the combustion of waste, and in particular the combustion of woody and agricultural residues from cereals, fruit or olive trees to produce power and heat are mainly extremely feasible for Lebanon. The feedstock resources are found in the majority of the regions, though they prevail in Beirut, North Lebanon, Mount Lebanon and the Bekaa.

D- Biogas conversion:

Both dry and wet biomass can be converted into biogas. The biogas production from "anaerobic" digestion of both sewage sludge and slaughterhouse waste is also remarkable for Lebanon, particularly in the most populated areas such as the Beirut, Mount Lebanon and the Bekaa regions where there is a shortage in treating the waste bulks. Nevertheless, there is a financial barrier to this technology group since several conditions need to be met for making the biogas projects economically viable.

Assessment of the sustainability impact:

The UNDP mentioned in its "National Bioenergy Strategy for Lebanon" that "*the development of a sustainable bioenergy industry depends not only on the available biomass potential and the economic performance of its conversion option(s). It also depends on its environmental and social sustainability. A condition for a sustainable bioenergy development is therefore to ensure that negative sustainability impacts are avoided*".

UNDP (2012) added that Lebanon holds the 90th rank in the 149 countries' list of the "Environmental Performance Index" (EPI) which covers the environmental health, air pollution, water resources, biodiversity and habitat, productive natural resources, and climate change.

In Lebanon, the environmental concerns are associated with the biodiversity loss, the climate change where is witnessed a high per-capita CO_2 emissions, the water-related problems where severe effects on ecosystems are perceived, and the high loads of air pollution. The latter, in addition to the mismanaged solid waste deployments, have a devastating impact on the environmental. Furthermore, solid waste remains a main environmental issue in Lebanon because of the 700 plus open dumps that municipalities are burning at a rate of 50%. This process is the major cause for underground water pollution and air pollution at the same time.

2.8.4 Solar (Photovoltaic) Power in Lebanon

As per the 2010's Policy paper, "*the average power generation costs of Lebanon's electric power utility, EDL were estimated to be 17.14 US cents per Kilowatt-hour (KWh), while the frequent power cuts have forced the population to rely on even more expensive back-up arrangements, typically consisting of diesel generators*". Also, the World Bank stressed on this fact by stating that 1/3rd of the Lebanese electricity demand is met through these privately-owned generators with a cost of over 30 US cents per kWh.

Figure 2-6 displays the gap between EDL's supply and demand in year 2009. Suppressed electricity equals the demand minus the supply in any given year (Suppressed = Demand – Supply). As shown in Figure 2-6, the suppressed electricity amount is considerable, hence,

new additional supply sources must be provided, otherwise the situation will be expected to exacerbate since the electricity demand is forecasted to increase at an average of 7% annually between the years 2009 and 2015.

To avoid this dilemma, the MoEW's 2010 Policy Paper included a plan to increase the total power generation capacity in Lebanon to 4,000 Megawatts by year 2014 and to 5,000 Megawatts subsequently. This target should be achieved with new and rehabilitated gas-fired power plants, as a part of the 12% renewable energy strategy until year 2020; power supply of 115-165 Megawatts, including new hydro (40 MW), wind (60-100 MW) and waste to energy (15-25 MW).

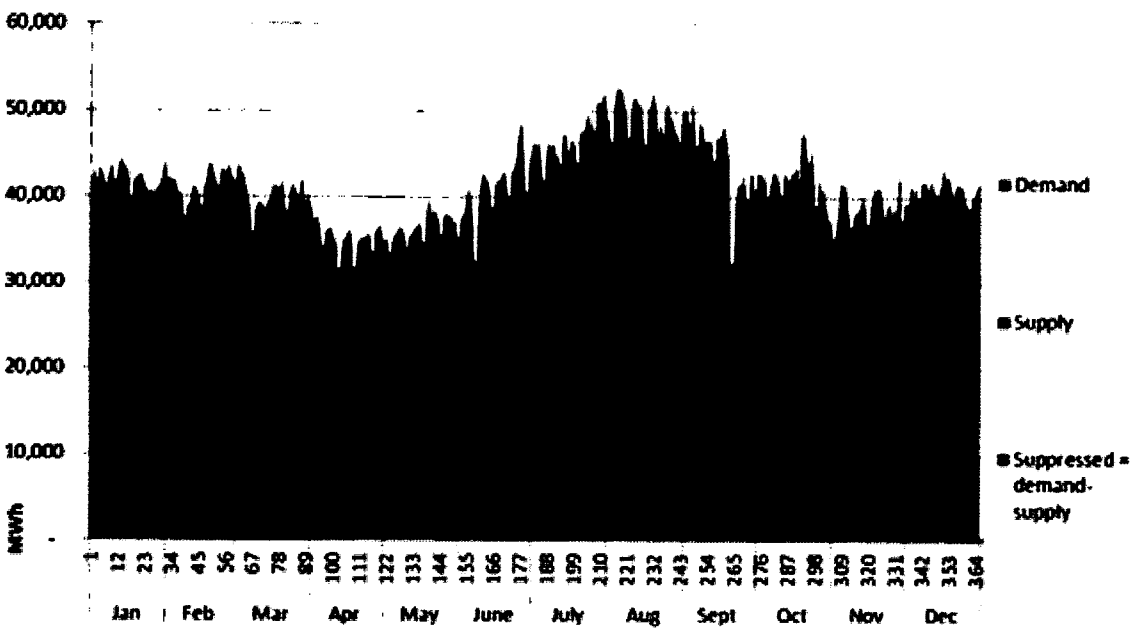

Figure 2-6 Daily demand, supply, and suppressed electricity in 2009 (Source: Harajli et al. 2010)

Another important factor aiming at offsetting today's electricity shortages in Lebanon is the individual power generation through Photovoltaic (PV) or solar panels. In other words, people can deploy solar panels on their rooftops in order to generate electricity for their personal use. As a result, "*a first regulatory scheme for grid connection of RE based generation was adopted in national legislation in November 2011 under a "net–metering" basis, aimed at enabling self-consumption*", as per UNDP's "Photovoltaic Power Plants in Lebanon - 2013".

Today, there are several private companies in Lebanon which started to install PV panels for private use with costs starting at 9,500 USD for 10 Amperes power generation.

In partnership with UNDP-CEDRO, the Lebanese Center for Energy Conservation (LCEC) introduced the concept of net-metering in September 2012. Under a brochure entitled "Net-Metering in Lebanon: Reduce your Energy Bill through Green Energy Production", LCEC defined net-metering as being a renewable energy initiative through which consumers with small renewable energy facilities can offset the cost pf power drawn from the utility. It added that this concept works by installing a meter that records the bidirectional energy flow, allowing the excess power to be transmitted to the grid, hence the exported energy from the system is subtracted from the imported energy, and the net output is calculated.

The UNDP described that the introduction of net-metering in Lebanon is important because it helps in;

- Developing the market
- Promoting the private investment in self-consumption plants
- Reducing the operation of private diesel generators
- Incentivizing the electricity sector to consider alternatives to the current monopolistic generation.

In addition to the individual power generation through PV, large solar farms were studied for implementation in Lebanon by UNDP under the CEDRO project in association with the MoEW. The solar farms are to be installed on different Lebanese locations. The UNDP stressed on the importance of the solar energy that Lebanon could benefit from because of the 300 plus sunny days that our country enjoys each year, with 1,934 sun peak hours.

Table 2-4 displays the financial analysis data of a 1.3 Megawatts PV plant in the Beirut area, calculated under three different scenarios;

Financial parameters (20 year analysis)	**Scenarios**		
	PV market not mature	PV market not mature 30% rebate	PV market mature
Initial investment funding mix	100% equity (or own)	30% rebate 70% equity	100% equity (or own)
Overall initial investment costs to cover with private funds	3,935,646 USD	2,754,952 USD	3,034,746 USD
M&O&M costs (Year 1 ref.)	94,808 USD/year	94.808 USD/year	46,365 USD/year
PR; PV plant yield	0.75; 2,070 MWh/year	0.75; 2,070 MWh/ year	0.83; 2,291 MWh/year
Output 1: LCOE	0.23 USD/kWh	0.18 USD/kWh	0.12 USD/kWh
Output 2a: if PPA tariff = 0.25 USD/kWh			
payback period	10 years	7 years	6 years
IRR @ 10 years	1.8 %	8.8 %	11.8 %
IRR @ 15 years	6.0 %	12.0 %	14.7 %
IRR @ 20 years	7.8 %	13.2 %	15.7 %
utput 2b: for IRR@20 years = 20% PPA tariff needed	0.45 USD/kWh	0.33 USD/kWh	0.30 USD/kWh
utput 2b: for IRR@20 years = 20% nd if PPA tariff = 0.25 USD/kWh rebate needed	50%	50%	19%

Table 2-4. Financial analysis of a 1.3MW PV plant development in the Beirut area under different scenarios (Source: UNDP – CEDRO, 2013)

Figure 2-7 displays the Cash Flow evolution for Scenario "PV market mature" with 100% equity funds and considering a Power Purchase Agreement (PPA) tariff of 0.25 USD/kWh, which would allow an IRR after 20 years of 15.7% (Table 2-4), and a payback period of 6 years.

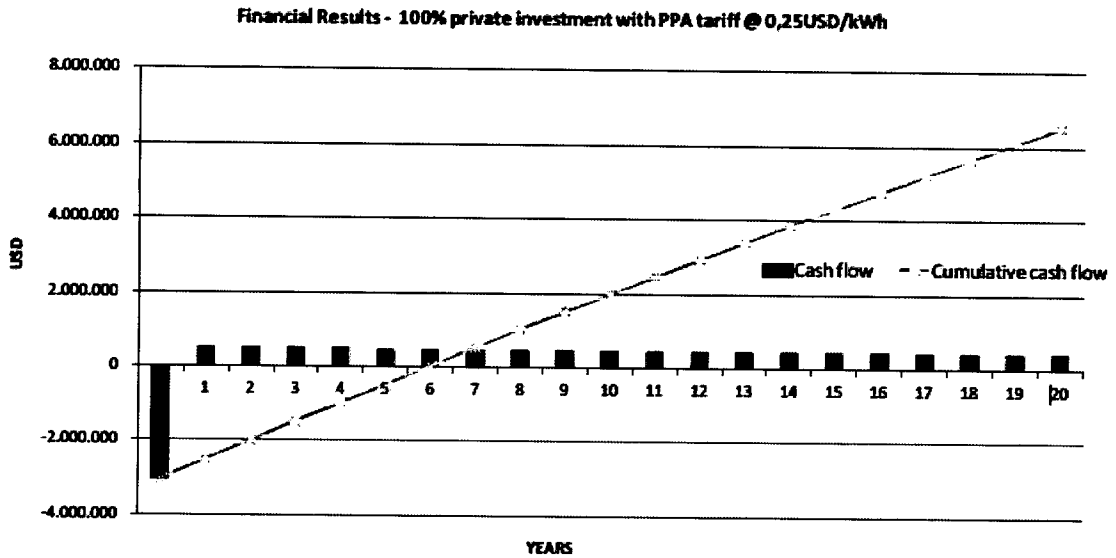

Figure 2-7 Projected cash flow evolution for a 1.3 MW PV plant in Beirut developed with private funds under a PPA selling tariff of 0.25USD per kWh; the IRR after 20 years would be15.7% (Source: UNDP – CEDRO, 2013)

2.8.5 Wind Energy in Lebanon

In its study on the wind potential in Lebanon, the UNDP released "The National Wind Atlas for Lebanon" in 2011 under the CEDRO project. Included in this study, the UNDP described that "*in the derivation of a national wind speed map it is desirable to calibrate the outputs of the wind flow models against actual ground based wind measurements recorded at locations within the model boundaries. Wind measurements collected at meteorological stations operated by the local national meteorological service can often be suitable for this purpose*".

As for Lebanon, the country holds a nationwide network of meteorological stations which are operated by Météo Liban (ML). ML has supplied "Garrad Hassan & Partners Ltd" (GH) with elementary information including monthly and hourly wind data from 17 and 5 different meteorological stations respectively, located in Lebanon, in order to analyze the wind map. ("Garrad Hassan & Partners Ltd" was employed by UNDP to consult for the Lebanese Republic concerning the wind studies).

Depending on the available data, GH defined the long-term seasonal variation in windiness based on Beirut International Airport, Beirut Golf, Tripoli, Sour, Kleyaat / Akkar, Al Abdeh,

Al Arz (Les Cèdres), Daher el Baidar, Bayssour, Zahleh Houch el Oumara and Rayak Amara meteorological stations only.

Lebanon's forecasted monthly long-term variations of windiness are depicted below:

Month	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec	**Annual**
indiness [%]	104.4	113.2	110	109.8	102.8	102	103.4	93.4	91.1	86.2	86.9	97.1	**100**

Table 2-5 Lebanon's forecasted monthly long-term variations of windiness (Source: UNDP – CEDRO, 2011)

UNDP stated in its Wind Atlas study that "*in order to provide an indication of the approximate amount of energy that could be generated by a single turbine installed at a given location, the indicative annual energy output for each power density band displayed in the supplied power density maps has been calculated*". The numbers displayed in Table 2-6 correspond to a generic 1.5 Megawatts turbine model with a hub height of 80 meters.

Power Density (W/m2)	**Annual Energy Output (GWh/yr)**
650	2.7
600	2.6
550	2.5
500	2.5
450	2.4
400	2.3
350	2.2
300	2.1
250	1.9
200	1.7
150	1.4
100	1.1
50	0.6
0	0

Table 2-6 Energy outputs for corresponding power densities (Source: UNDP – CEDRO, 2011)

2.8.6 Wastewater Potential Energy in Lebanon

While he was Minister of Energy and Water, Gebran Bassil confirmed that "*we* [the MoEW] *firmly believe that a stable energy sector is one that is diverse and secure. It is within this mindset that the Ministry of Energy and Water is considering all available options for the development of the national energy sector. Our commitment to ensure a stable energy sector goes hand in hand with our intention to develop this sector according to the highest standards of environmental sustainability*".

UNDP's "Energy from Wastewater Sewage Sludge in Lebanon" report in 2013 has acknowledged five Wastewater Treatment Plants (WWTPs) that meet the requirements for the implementation of at least one sludge "Anaerobic Digester". These plants are located in Sour, Aabdeh, Sarafand, Saida and Majdal Anjar.

As per OILGAE, "*anaerobic digestion is a collection of processes by which microorganisms break down biodegradable material in the absence of oxygen. The process is used for industrial or domestic purposes to manage waste and/or to produce fuels*". In addition, anaerobic digestion can be used to produce methane which generates two by-products; Biogas and efficient digested residues used as fertilizers for land application. This process has several important advantages including the generation of renewable energy, the treatment of organic wastes generated by industries, agriculture, wastewater treatment plants, and municipalities (A ton of organic matter destroyed produces approximately 0.9 to 1.1 Nm^3 of biogas), and finally the production of efficient fertilizers.

An important note is that today, Lebanon has an anaerobic digester unit already implemented in Tripoli. UNDP added that the total energy supply that is expected from the five plants is projected to be 143,000 Megawatt-hours (MWh). This number translates into 5.9 Megawatts of installed electrical power. The anaerobic digestion implementation of the five WWTPs permits a considerable reduction of greenhouse gas emissions of around 20,500 tons of CO_2 equivalent.

In addition to the aforementioned, the UNDP executed a plan for small to medium WWTPs that allow an average 70% increase in energy production with an installed electrical power of 11.6 Megawatts. Hence, the total energy supply is forecasted to be 237,700 MWh.

Consequently, all WWTP projects permit a reduction of approximately 35,000 tons of CO_2 equivalent. Altogether, these energy production projects may well constitute 3% to 4% of the national bioenergy potential mentioned in the 2012's "Bioenergy Strategy Plan".

	Primary Energy	**Energy production through CHP**	**Electrical Power**	
	kWh/year	Electricity MWh/year	MWh/year	MW_{el}
Tripoli Project	61,455,882	23,968	52,238	3
Sour Project	18,505,290	7,217	15,729	0.9
Aabde Project	28,232,775	11,011	23,998	1.38
Sarafand Project	30,567,253	11,921	25,982	1.49
Saida Project	34,898,904	13,611	29,664	1.7
Majdal Anjar Project	34,898,904	13,611	29,664	1.7
Bekaa Project	29,218,369	11,395	24,836	1.42
TOTAL	**237,777,377**	**92,733**	**202,111**	**11.59**

Table 2-7 Main energy output findings (Source: UNDP – CEDRO, 2013)

Lebanon's current industrial electricity prices were used in order to evaluate the simple "payback" of the capital investment from the annual returns. Also, the levelized cost of electricity was assessed by taking into consideration a 15-year lifetime and an 8% discount rate. The financial analysis is applied to the projects that are assigned for co-digestion (Projects 3 to 7). Table 2-8 shows the expected payback period of the projects, whereas Table 2-9 displays the levelized cost of electricity delivered.

PROJECT	CAPEX	Annual Electricity Generation (KWh)	Revenue/year	Payback (yrs)
Project 3 WWTP	€ 5,535,000	5,961,592	€ 344,640	16
Project 3 Co-dig	€ 6,320,530	11,809,720	€ 682,720	9
Project 4 WWTP	€ 7,925,244	8,840,598	€ 511,075	16
Project 4 Co-dig	€ 8,287,734	12,340,056	€ 713,379	12
Project 5 WWTP	€ 9,273,863	10,652,801	€ 615,838	15
Project 5 Co-dig	€ 9,550,153	13,984,145	€ 808,423	12
Project 6 WWTP	€ 7,396,849	8,240,278	€ 476,370	16
Project 6 Co-dig	€ 8,079,675	14,374,669	€ 831,000	10
Project 7 WWTP	€ 3,939,370	3,919,844	€ 226,606	17
Project 7 Co-dig	€ 5,320,316	12,642,687	€ 730,874	7

Table 2-8 Payback period of identified options with and without co-digestion (Source: UNDP – CEDRO, 2013)

It is clear from Table 2-8, that if the co-digestion projects are excluded from Lebanon's calculations, then the economics of the clean renewable energy supply from AD are not encouraging. To confirm this, UNDP stated that co-digestion is very important to boost the economics of the Lebanese system, hence energy supply from WWTPs should not be left out.

	Without Co-digestion ($c/kWh)	With Co-digestion ($c/kWh)
Project 3	19.7	8.7
Project 4	16.1	10.6
Project 5	15.6	10.7
Project 6	16.2	9
Project 7	7.7	7.1

Table 2-9 Levelized electricity costs ($c/kWh) from 5 selected WWTPs in Lebanon (Source: UNDP – CEDRO, 2013)

Table 2-9 clearly shows that the projects' estimated costs for each KWh are below the current average generation costs of the Lebanese electricity system that range between $c20-30/kWh (prices vary subject to international oil prices). In addition, the combination of co-digestion is

crucial in the delivery of much better levelized cost estimates, and consequently it should be targeted as well.

2.8.7 Hydro Power from Non-River sources in Lebanon

In its 2013 study entitled "Hydropower from Non-River Sources; the Potential in Lebanon", UNDP confirmed that "*the challenges of the Lebanese Electricity sector are not limited to meet the Energy demand through the timely increase of the installed generation capacity but also to enhance a diversified mix of energy sources in which the sustainable Renewable Energies play a major role*". This statement depicts the reality that Lebanon is facing concerning its electricity generation to try and cover the power shortages through new installed capacities and of course the implementation of the renewable energy through solar, wind, hydro, etc.

Assessing hydropower potential from various non-river water sources is also under the 12% renewable energy target by the year 2020. The water systems in this study are the irrigation systems, the drinking water systems, the electrical power plant outfall pipes and the wastewater treatment plants.

Thirteen (13) sites were selected from the Lebanese territory for further action and evaluation in terms of technical and economic standpoints. The estimated total electrical power potential resulting from these sites accounts to an approximate 5 Megawatts. Figure 2-8 displays the diversification of this hydropower potential where than 50% was found in the existing Lebanese thermal power plants. In addition to their high ability to provide energy, the sites require remarkably low investments, and accordingly they have short payback periods.
The "drinking water" systems are expected to have high hydro potential in Lebanon, however the existing pipelines used for distribution possess high level of resistance because of their small diameter and their reasonably good flow. Therefore, this could be considered as an advantage and a drawback at the same time. As for the WWTPs, these do not possess a substantial potential for power generation, in contrast, they may be under the energy efficiency measures

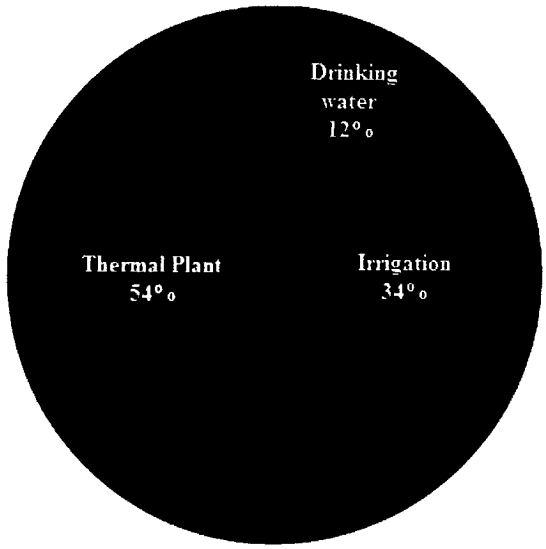

Figure 2-8 Energy potential of the visited sites in Lebanon (only non-river sources) (Source: UNDP – CEDRO, 2013)

In Lebanon, the electricity cuts constitute a daily occurrence because the demand for power exceeds EDL's supply capability. In addition, this demand is forecasted to get over 4,000 Megawatts by the year 2015, as per the "Document of the World Bank, Republic of Lebanon, Electricity Sector" executed in 2008. The year 1998 was the last year that witnessed an implementation of combined cycle power plants. These were in Zahrani and Beddawi, and since then no new power plants has been added to meet the constantly growing electricity demand. Additionally, the Lebanese electricity tariffs have not been adjusted since 1996, leading to the inability of covering the cost of power generation. Today, same as the year 2006 for instance, the overall average electricity tariff is was 141 Lebanese Pounds (LBP) per Kilowatt-hours which translates to around 9.4 US cents per Kilowatt-hour. This tariff is based upon the 1996's oil price which was 25 USD per barrel. This price is now outdated since it has not been adjusted to include any sort of inflation in addition to the significant increase in the national oil price. Subsequently, the current electricity selling tariff is excessively low, hence unable to cover the electricity generation costs, which on average at this time, account for at least 19 US cents per Kilowatt-hour. Besides, the private generators are costly and impose additional tariffs on Lebanese consumers making the total tariffs high in comparison with other countries but still not enough to cover EDL's costs nor at least reach its break-even.

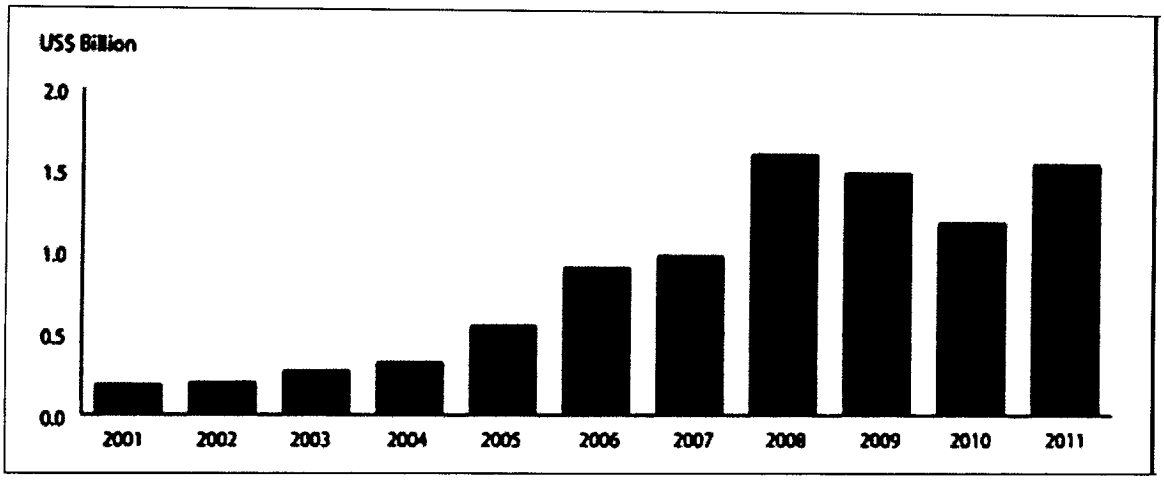

Figure 2-9 Ministry of Finance transfers to EDL (in USD Billion) (Source: MoF, 2010)

In UNDP's "Hydropower from Non-River Sources; the Potential in Lebanon", the objective is to assess the potential of generating micro-to-small hydro power from non-river based water sources such as;

1- Irrigational Channels and Conveyers; hydro power plants must be designed in a sort to make prime use of available "head and flow" at different irrigation systems
2- Wastewater treatment plants inlet and outfall pipes; there are two concepts either by installing a turbine at the inlet of the WWTP using untreated water, or by using the treated wastewater before returning it to the receiving water
3- Thermal power plants' outfall pipes; making use of the thermal power plants' cooling water is the objective in this category. The cooling water is usually drawn from the sea, then pumped into the "heat exchanger", and finally returned the sea. What can be done is set up a turbine at the outlet of the discharge cooling water structure at any of the thermal power plants
4- Drinking water distribution networks; there are two concepts either by installing a turbine at the entrance of the reservoir/storage tank at the water distributing station, or by installing it within the supply networks.

Hydropower from non-river sources can increase the renewable energy supply by delivering power up to 5 Megawatts, which is equal to approximately 27.4 million Kilowatt-hours per year. These figures account for delivering electricity to 5,477 homes assuming a 5,000 Kilowatt-hours annual electricity demand per household. Moreover, another and yet major

benefit is the CO_2 emissions reduction that these plants can offer, where approximately 17,800 tons of CO_2 equivalent would be saved annually.

Site Name	Type
Naher el Bared lake	Irrigation System
Brak spring	Irrigation System
Wadi El Hojeir	Irrigation System
Ain Leghwaibe (b)	Irrigation System
Younin	Irrigation System
Nebe Al Safa irrigation	Irrigation System
Qasimia Irrigation System	Irrigation System
Falouss Irrigation System	Irrigation System
Tripoli water treatment plant	Water Treatment Plant
Saida water treatment plant	Water Treatment Plant
Jiyeh treatment plant	Water Treatment Plant
Zahrani Power Plant	Electrical power plant
Zouk Power Plant	Electrical power plant
Jiyeh Power Plant	Electrical power plant
Deir Ammar Power plant	Electrical power plant
Hrayche Power Plant	Electrical power plant
Saida water station (a)	Water Distribution Networks
Saida water station (b)	Water Distribution Networks
Kaa el Rim	Water Distribution Networks
Ain Leghwaibe (a)	Water Distribution Networks

Table 2-10 Lists the visited sites and their types of hydropower sources (Source: UNDP – CEDRO, 2013)

In the case of the thermal power plants, the "relevant tariff" for the hydro power production is the production costs per Kilowatt-hour of around 19 US cents (per Kilowatt-hour). On the other hand, if the government owns the hydro and the thermal power plants, then it can save the cost for "subsidization", which compels selling the much expensive produced electricity

(costing at least 19 US cents per Kilowatt-hour), at very low tariffs to the consumers (of around 9.4 US cents per Kilowatt-hour).

2.9 Conclusion

Bulkin (2003)'s energy future demand for power generation and electricity are;

1- *Growth in demand, expected to continue without much constraint; world demand for electricity projected to grow at* ***2.6%*** *per annum for the next two decades (2.3% as per EIA)*
2- *Growth in nuclear power, but not as fast as predicted, because of fears of danger, fears of proliferation, and inability to deal with waste*
3- *Growth in the use of natural gas, and in the efficiency with which it is used, with combined cycle gas turbines becoming a dominant technology*
4- *Levelling off of the use of coal, with either low-sulfur coal or scrubbing techniques becoming dominant in the US and Europe, and with coal being a higher cost than gas for new plants in most locations*
5- *Reduction in the use of oil, likely to continue*
6- *Rapid growth in renewables, especially wind and solar, but from a very small base, so still remaining as a very small share of the total fuel mix*

Today, the energy security is considered one of the most crucial objectives in the worldwide economies. Hence, diversifying the energy supply is a major goal, and Lebanon is no exception. As the concept of diversification in a financial portfolio, the diversification of energy sources intensifies the resilience of the electricity systems in order to overcome any difficulties concerning fuel price fluctuations and fuel source stoppages. As a result, every Kilowatt counts.

In a concluding statement, The "UN/World Energy Council" submitted the report "World Energy Assessment" in 2000 in which it described that "*there are no fundamental technological, economic or resource limits constraining the world from enjoying the benefits of both high levels of energy services and a better environment*". It also added that "*a prosperous, equitable and environmentally sustainable world is within our reach, but only if*

governments adopt new policies to encourage the delivery of energy services in cleaner and more efficient way".

All the previous opinions and statements call for the need to conduct a study in Lebanon. The aim is to highlight the importance of the renewable energy in Lebanon in terms of sustainability and social responsibility. Consequently, the research question is: "**How do experts in Lebanon perceive the need and importance of renewable energy? (The Case of Electricity)**".

Chapter 3

PROCEDURES AND METHODOLOGY

3.1 Introduction

Following the literature review concerning the sustainability of the energy sources, the importance of the green economy harvested through green power, and the social responsibility towards the environment protection, the research question is: "**How do experts in Lebanon perceive the need and importance of renewable energy? (The Case of Electricity)**". To answer this question, I based my analysis on the interviews I conducted with the experts related to the energy field. The objectives are; one, to stress on the importance of the sustainable energy sources and the benefits they can offer for the sake of our environment. Second, to draw the attention of the people and perceive the degree of awareness concerning the current energy production methods that could lead the abolition of life on Earth. Third, understand the opinion of the experts concerning alternatives for the electricity supply in Lebanon.

3.2 Methodology

The methodology in this paper is exploratory, secondary data concerning the renewable energy sources are used in addition to the different opinions and statement from various researchers and analysts. Also, the methods include interviews with Lebanese experts concerning the implementation of renewable energy in Lebanon. The data is primary and therefore is qualitative.

3.2.1 Data Collection Method

3.2.1.1 Primary Research

A research is defined as qualitative if "*the purpose of the study is primarily to describe a situation, phenomenon, problem or event* [...] *and if analysis is done to establish the variation in the situation, phenomenon or problem, without quantifying it*" (Kumar 1999).

When understanding Kumar's definition, then this study is best described as Qualitative with the main purpose of exploring the perception of the Lebanese experts concerning the renewable energy sources and their implementation in Lebanon, without trying to quantify it. Consequently, the primary idea is to use semi-structured interviews as a research methodology to form a picture of the situation in Lebanon related to the renewable energy sources as perceived by the Lebanese experts.

3.2.1.2 Secondary Research

Every research project should include secondary research because secondary data gives on overview of what has been researched before in the same subject area, which will not only help to choose a research topic and place the research in context, but is also crucial for the decision on research design for the own research (Greenfield 1996 and Bell 2001).
The secondary research for data started with peer-reviewed articles on the Sustainable Development, the Green Economy, and the Social Responsibility concerning the renewable energy sources, from the Notre Dame University (NDU) e-library.

To get a richer objective view of the theories, articles and books that discussed the three abovementioned topics were required. To find more sources, the bibliographies of the texts that were already used were screened, and as a result much more relevant literature was found. When I believed to have found enough information on the relevant topics, the remainder of the literature review was written, increasing the focus towards the final research area. It was decided to discuss the literature in two parts so that the structure would not become too complex and the overview could be kept. The first part concerns the Sustainable Development, the Green Economy, and the Social Responsibility in the arena of the renewable energy sources. The second part discussed the case of Lebanon concerning these renewables in terms of studies and researches mostly conducted by the MoEW and the UNDP under the CEDRO projects.

3.2.2 Description of the Interview Questionnaire

I conducted ten (10) interviews with the Lebanese energy experts. The interview questionnaires consisted of fourteen questions divided into five sub-categories. The questions were meant to reflect the awareness, the understanding, the need, the importance, and the feasibility of the renewable energy sources' implementation in Lebanon and worldwide concerning only the SPS.

3.3 Analysis Technique

The objective of the analysis was to "draw a picture" of the Lebanese experts' perception regarding renewable energy sources implementation in Lebanon as well as their regard to the SPS platform conception. Therefore, no use has been made of established analysis methods but each interview questionnaire was regarded as a separate unit. The objective was to use the answers to the questions to form a general idea on the renewables topic in Lebanon and what are the initiatives that will be taken concerning this topic.

Chapter 4

FINDINGS

4.1 Introduction

This chapter presents and interprets the results from the primary research performed for this study. The analysis will begin with the semi-structured interviews conducted for this study, in addition to the observations from the questions that were used to derive the perception concerning the renewable energy sources in Lebanon. Succeeding this, the results will be presented and then compared with the literature found in the secondary research. Finally, I will give comments on the correspondence of the existing results.

4.2 Descriptive Statistics

4.2.1 Sample

The total sample used for the analysis consisted of ten interviews with the same questionnaire each time; out of which four were conducted as a one-one interview, four were collected via e-mail correspondence, one through a telephone conversation, and one via a "Skype" call.

I am aware of the fact that the sample is perhaps small in order to produce consistent results, but tentative conclusions on the findings that are available were conducted, which in the case of exploratory research should be acceptable.

The interviewees were chosen in a manner to include;

- Senior experts such as Chafic Abi Said and Nader Shahadeh.
- UNDP experts such as Hassan Harajli.
- Public sector experts such as Rani El Achkar.
- Private sector experts and managers such as Georges Abboud, Lara Chalekian, Michel Madi, and Fares Abi Dargham.
- Energy experts and Professors at universities such as Ahmad Houri and Joseph Al Assaad.

4.3 Main Results

The questions in the interviews have been used to make conclusions regarding the perception of the Lebanese experts on the renewable energy topic, its implementation in Lebanon, its eco-friendly aspect, and finally highlight the perception of these experts on a proposed solution which is the SPS. All the questions were intended to focus on the Lebanese electricity sector in terms of existing power production methods and integration of renewables into the process.

For a complete list of the interview questions and the interviewees names, please check Appendix A.

The answers of the interviewees were combined altogether to form the analysis in this chapter, meaning that the collected data was pooled from the different answers and presented in a straight manner. The answers constituted a unanimity regarding the Lebanese electricity sector, the importance of the renewable energies, the need to implement these in Lebanon and that the SPS concept is still far-fetched where some experts stated that it not feasible and just a theory.

The experts confirmed altogether that the Lebanese electricity sector is under a crisis. This is because the last electricity power plant has been maintained or rehabilitated in the year 1996. Since then, no addition of new power plants has been implemented, nor rehabilitation of any of the existing ones, has been conducted. An important factor leading to the power shortages in Lebanon, is the fact that the demand outweighs the supply provided by Electricté Du Liban (EDL).

4.4 Discussion of the Findings and Other Observations

4.4.1 The Current Lebanese Electricity Sector; the CRISIS

Lebanon has a major shortage in power plants which are not enough to cover the current or the upcoming demand as per Chafic Abi Said. Also, he added that there is a shortage in investments concerning the electricity sector where the last fund was made in the year 1996.

And since the year 2000, there has been no additional electricity production in Lebanon although the demand is constantly growing.

Hassan Harajli explained that the primary cause for the power shortages problem is the Lebanese government's negligence and mismanagement concerning the electricity sector. He added that the government owns the sector from generation to distribution but the right investments were not chosen. In addition, the Lebanese population is growing, side-by-side with the economic growth (even if Lebanon witnessed a number of crises, the economic growth was still increased by 1 or 2%). Therefore, the Lebanese need for energy is growing rapidly each day. The problem is not being able to build new power plants that satisfy this need for energy. For example, the Zouk plant which is supposed to deliver 400 Megawatts, is delivering 300 Megawatts; this is because it needs maintenance. This was in line with Rani El Achkar who added that the most important drawback is the grid problem which is divided into technical and non-technical losses. The former constitute around 20% and is defined by the transmission and the distribution lines which do not comply with the standards nor the specifications needed. The latter constitute around 15% and is defined by the lack of electricity bills payments in some Lebanese areas in addition to electricity "theft". The total of these losses constitutes around 35% which is beyond of what is internationally accepted.

Moreover, Chafic Abi Said stated that the Lebanese government holds plants that deal with Natural Gas, which Lebanon doesn't have or produce. As a replacement, diesel oil is being processed in these plants, which creates environmental problems instead of alleviating them. Therefore, in place of having a 100% capacity, Lebanon is yielding around 40 to 50% maximum capacity of the generated electricity which is also hurting the environment.

As for the cost, Hassan Harajli confirmed that for example in England, if a family pays more than 10% of its income on energy, then it is considered "fuel poor". In Lebanon, 50% of the people pay up to 30% of their income on energy. This is because they pay for EDL's bills, the private neighborhood generators' bills, and most importantly the cost of **not** having electricity. Harajli added that this is called the "value of loss load" which is defined by the value of money paid due to power loss. For instance, if people pay 100 USD per month for

the private generates for a supply of 5 Amperes, then this amount accounts for the value of loss load which is the money paid to receive power when the electricity is cut.

Above and beyond, Rani El Achkar described that the net cost of a Kilowatt-hour produced by the EDL is around 18 to 20 US cents, whereas it is sold at 10 US cents. Hence, EDL is incurring huge losses each year which is affecting the economy. This is because the electricity Kilowatt-hour price was fixed in the year 1996. Before that year, the Kilowatt-hour cost used to vary according to the world fuel prices. In addition to not following the fuel prices, from 1996 till today, the prices didn't even increase to follow the Lebanese inflation. So the EDL is stuck with same pricing while the price of everything else has doubled or even tripled. Nevertheless, increasing the Kilowatt-hour price is not potentially feasible at this moment because of the constant financial problems in the country. Yet, Joseph Al Assaad stated that the plan is to increase the electricity tariffs in year 2015 since then the electricity will be delivered 24/7 according to the initial 2010 action plan executed by the Minister of Energy and Water at that time, Gebran Bassil (year 2014 is the target year). So, the argument would be that now, people are paying the electricity tariffs in addition to private generators' tariffs which is around 100 to 150 USD per month. This amount will still be paid but under the form of an extra electricity tariff implied by the government who will provide a 24/7 electricity power. Therefore, the losses will be compensated and the extra money will be used to build new electricity plants and/or maintain the existing ones.

Ahmad Houri insisted that the question that remains is the following; is a power plant environmentally friendly? The answer is no. Does that mean that we should shut down all power plants and live in the dark? Again the answer is no. Houri affirmed that power supply through barges or diesel burning generator in general is a very expensive and polluting option, but when compared to the cost of private generation or the cost of electricity outages, then it becomes the better solution.

In the same context, Nader Shahadeh described that if there is anything much worse than harming the environment, the current power production methods are doing it. Around 94% of the produces electricity is from burning fossil fuels which in any form harms the environment by producing massive amounts of CO_2. He added that more importantly however, the burning

of diesel and heavy fuel oil has the added disadvantage of sulfur oxides and other acid-rain-causing gases. Usually, and among fossil fuels, coal is considered the worst fuel while gas is considered the least polluting. So irregardless of the barges/ships, the methods used to burn fuel oil are the ones that matter. For example, if the fuel oil has a good quality, and its burning methods are abiding to the environmental laws, then the result is not bas as people think, and vice-versa. In addition, the Zouk plant is now implementing fuel oil having with less sulfur percentage (from 3.5% sulfur to 1% in Zouk, and 2% in Jiyeh). Nevertheless, the best solution is the natural gas. And if the latter cannot be found, liquid gas can be bought and then converted into natural gas.

Chafic Abi Said confirmed that the new plants in Zahrani and Deir Ammar were built with the ability of deploying natural gas. This plan included buying natural gas from Syria and install a pipeline from the North to the South of Lebanon passing through the coast. In fact, a pipeline connecting Damascus to Deir Ammar's plant was installed. Once the pipeline was completed, the Syrians affirmed that they were unable to provide Lebanon with natural gas since they had no enough quantity, although an agreement was made. He stated that this was in late 1990s, and until today, nothing has been made concerning this project although it could have been committed to private organizations under the private sector. Instead of the natural gas, Lebanon employed the gas oil which is less polluting than the fuel oil (but more polluting than natural gas), however is much more expensive than the latter.

So, the population growth, the economic growth, the current plants not being rehabilitated, and the transmission and distribution losses, have resulted in an energy demand way outstripping supply which is affecting the Lebanese economy one way or another. In short, the fact that Lebanon is having power shortage in addition to the government's payments to EDL as subsidies because the latter is incurring losses, is more than enough to call the electricity problem a crisis. In addition, the private sector is also forced to deploy private generators which makes it worse as per Hassan Harajli.

4.4.2 Sustainability and Social Responsibility towards a Green Economy

The renewable energy sources are getting momentum in Lebanon especially with the increased awareness, their growing market share, and their constant decrease in prices, as per Lara Chalekian. This is why the Ministry of Energy and Water, organized a plan in 2010 in which it indicated that in year 2020, Lebanon will have 12% of its energy in form of renewables. This was an action plan referred to as "Policy Paper". It was executed by the minister, aided by energy experts and researches.

We have today around 6% or less of the electricity produced by renewable energy sources. This number is not acceptable internationally; the majority of the world's countries have set policies and targets concerning a percentage of renewable energy to be deployed. For instance, Egypt has put now a target of 30% renewable energy. Also, the "European Union" (EU) has put a target of at least 20% by the year 2020.

The policy paper stated that in year 2014, the Lebanese territory will have a 24/7 schedule of electricity with no cuts. Included in the plan was also to bring in barges for energy delivery (such as "Fatma Gul") in addition to restoring and/or repairing the existing electricity plants that operate on a very low efficiency (such as Zouk, Jiyeh, and Zahrani plants).

Joseph Al Assaad stated that the Lebanese government is working on the renewable energy sources and energy efficiencies in parallel with the conventional power plants. To back the 12% renewable energy target by the year 2020, the Lebanese government started to implement the "National Energy Efficiency Action Plan" (NEEAP) in 2011 consisting of 14 initiatives divided into energy efficiency and renewable energy. The NEEAP is now considered as a formal action plan irregardless of the current or upcoming governments since it was approved by the council of ministers. Therefore, it will proceed no matter who or what the Lebanese regime is. He added that the NEEAP comes under the Arab countries initiatives' for energy efficiency with Lebanon being the first nation to implement this strategy. This was in line with Rani El Achkar who stated that there are several initiatives about to be completed while others that just had started. Also, there are some initiatives that were not mentioned in the NEEAP but are being achieved faster than the ones existing in the plan. For example, the energy efficiency lamps, the energy conservation law, the decentralized power production

(photovoltaic or solar, and wind) depicting that individuals can produce power at their premises, the public street lighting, etc. Also, there is an initiative for energy efficient buildings where a draft code for Lebanon was written with the help of the urban planning committee from the Ministry of Public Works and Transport. Then it was sent to the Engineering Syndicate for intensive studies. Now, it is currently being translated in order to present it to the council of ministers for final approval.

In addition to the NEEAP, and the Bassil's 2010 action plan, Lebanon is now in the process of setting the "Renewable Energy Strategy" in order to achieve the 12% renewable energy by the year 2020 goal. This strategy is not issued yet, but it will be in the very near term. Also, a new NEEAP will be issued in year 2015 encompassing only the energy efficiency initiative alongside a separate document for the renewable energy initiatives as per their current strategy studies.

The idea of the 2010's Policy Paper was to start with the restoration of the Lebanese plants, and in order to avoid electricity cuts off the people meanwhile, the government would employ barges form outside countries to compensate the lack of power caused by these repairs. This was the best proposed solution for the Lebanese plants maintenance; i.e. "rent" or "import" electricity from abroad. This strategy aims at increasing the supply while increasing the electricity production through rehabilitation and maintenance of the existing plants at the same time.

Hassan Harajli described that going back, when Gebran Bassil was appointed minister of energy and water, he selected a number of experts who studied (alongside with him) all the previous projects concerning the electricity sector. This was in order to update the existing projects and propose new ones. Bassil was the first to submit an action plan for the electricity sector in terms of a short term and long term plan. In the former, he planned for new power plants construction which takes up to 6 years in order to at least keep the same level of supply at first stages, then consider to satisfy the Lebanese power demand. From this came the idea of Fatma Gul which is similar to a power generator, used to "bridge the gap" of the existing demand because usually in Lebanon, every year we witness a 7% increase in power demand.

So, the main idea in Bassil's action plan is to maintain the existing power plants so that their efficiency gets back to 100% of supply. For example, if a plant is to supply 500 Megawatts then its delivery will be exactly 500 Megawatts. Hence, eliminating the losses is the prime objective. Also, investment in the distribution and transmission networks to minimize the losses were proposed. In addition, new power plants were being proposed for construction in Jiyeh and Deir Ammar (North of Lebanon). As for the Zouk plant, rehabilitation has already began, and new technologies for decreasing pollution are being implemented.

In other context, Hassan Harajli added that an important topic is the UNDP's projects who initiated the "Demand Side Management" plan in Lebanon aiming at decreasing the energy use, i.e. energy efficiency. The project involved the distribution of several solar energy panels, zero-interest solar panels loans, etc. As a result, some Lebanese municipalities started to adopt designs for LED street lighting and solar power generation for public streets. For example, the municipality of Kornet Chehwan, is implying policies for any new building project in Biyada and Kornet Chehwan. Each new building is obliged to have solar water heaters installed or will not be permitted to be constructed.

This was in line with Michel Madi who affirmed that all of this is in the sustainable electricity consumption framework, but a successful plan would be a combination of both the sustainable electricity consumption and the increased electricity production through renewable energy sources. Therefore, more awareness is required especially that the per capita electricity consumption is high in Lebanon.

Hassan Harajli said that the 2010 action plan was not entirely aimed at conserving the environment. Its prime objective was to satisfy the Lebanese electricity demand at first stages, then reconsider the environmental issues later on. This statement was confirmed by Bassil, because he thinks that the Lebanese people are more interested in a 24 hrs/day of electricity rather than 12 hrs/day with environment conservation. Therefore, the prime concern is to cover this demand as a first step and increase the electricity production in any way, then move to rethink the ways of this process.

4.4.3 Renewable Energy in Lebanon

As per Chafic Abi Said, renewable energy sources are the best alternative for substituting the conventional electricity production methods. For instance solar, wind, and hydro energies are examples of clean efficient energy sources. These sources need to be developed more in Lebanon; in fact Hassan Harajli confirmed that the hydro section has witnessed some development in Litani, Nahr Ibrahim, etc. with a 50% increase in supply. Nevertheless, the remaining potential is endless whether in hydro, wind and even solar which is starting to get popular through the thermal water heating that can decrease the electricity bill amount by 20%. This technology is now understood by the people, plus, there are several facilities concerning this implementation though bank loans with near-zero (if not zero) interest rates. The photovoltaic is starting to get momentum with the support of the World Bank, UNDP, and EU, also involving low-interest rates on concerned loans.

Starting with the energy efficiency lamps which people are getting more familiar with, moving to the public street lightings, the solar water heaters which are also being implemented in a very high pace, the large-scale wind farms, the large-scale solar farms, the hydro power, the new geothermal technologies, the new building code for Lebanon, the financing mechanisms and incentives, the Energy Service Companies (ESCO) business, and finally the energy efficient equipment. These are the plans for the renewable energy implementation in Lebanon as per the NEEAP, as per Rani El Achkar.

Concerning the energy efficient lamps, these should be approved by the Lebanese labs following European conditions to make sure they are energy efficient. The LCEC, along with the Lebanese government, distributed three million lamps in order to increase the awareness and encourage people to deploy such lamps at their homes. Lara Chalekian stated that today, people got the idea, and are now used to the energy efficient lamps since they are buying them more often. This is because they witnessed the difference in their electricity bills where the aforementioned lamps are not only energy efficient but also economical. This was in line with Hassan Harajli who confirmed that the three million lamps initiative was registered under the UNFCCC (United Nations Framework Convention on Climate Change), and also was under the "Clean Development Mechanism" (CDM) initiative. Nader Shahadeh explained the CDM as an agreement between the world's countries stating that each one has a certain limit of

carbon emissions that cannot be exceeded. The agreement also included a condition for countries (like Germany for example) which cannot stop or decease their industrialization, are allowed to exceed their carbon emissions' limit by a certain amount, but in return, it must compensate this same amount by funding a project in another country (a third-world country) to decrease their emissions by the same exact amount exceeded. This process is like buying credits from other countries, all having the aim of reducing carbon emissions. So the process is described by dividing the world countries into 2 sections; "annex 1" and "non-annex 1" countries. The former are the developed countries which are more responsible in contributing to the global warming through greenhouse gas emissions, more than others. While the latter are the developing countries which have the right to develop in a certain way at the expense of the environment. Lebanon was classified as a non-annex 1 country. These nations (non-annex 1) can undertake any power supply project which emits less carbon, and therefore "sell" the saved carbon amounts to the developed countries (annex 1) so these can bridge their carbon excess gaps.

Also, the LED lamps with the financing mechanism (zero-interest bank loans) are getting more and more popular. The decentralized power production (PV) with the financing mechanism (more than 50 solar power generation projects, under loan banks) are also in place. Moreover, the solar water heaters are very common today in Lebanon, and people are encouraged to implement them since the zero-interest bank loan is also applied. In addition, the Public Street Lighting project in terms of energy efficiency and solar power generation where 1,500 photocells were distributed to different Lebanese municipalities, was also pursued, as per Rani El Achar.

The zero-interest bank loans, the 1,500 distributed photocells, and the three million distributed lamps, were funded by the Lebanese government in 2010. This was because each winter, the government supports the diesel oil prices so that people can benefit from its decreased price to fulfill their winter needs in terms of heating. In the year 2010, the government had a surplus of money because the weather improved and winter was short. Therefore, the minister decided to employ this money into renewable energy and energy efficiency. So instead of supporting the diesel oil which is polluting the environment, why not

support other energy sources that limit this pollution. The same concept was applied in the 2011 winter, but was executed with less money.

4.4.3.1 Wind Power

The LCEC, in correspondence with the UNDP (under CEDRO project), were able to execute the project ATLAS for wind power supply, as per Hassan Harajli. Conversely, the Lebanese government forbids trading power as in energy supplied by the private sector. In other words, no one other than the government is allowed to sell his produced electricity, as per the Lebanese law. Individuals or the private sector can produce electricity, but for personal use only. The barges (such as Fatma Gul) were allowed to provide Lebanon with power under the definition that the Lebanese government was "renting" electricity from the private sector and not that the latter was producing and selling electricity. Therefore, the law bypass that was applied to bring in the barges, was approved to also be applied on the renewable energy sources. Therefore, a tendering was executed for a wind power plant that delivers between 50 and 100 Megawatts. After the bid, four proposals stood up (with each delivering between 50 and 100 Megawatts), provided by private companies (described as the private sector). Each company suggested a location on the Lebanese territory in order to place the wind farm. These four wind farms proposals are now in the hands of the LCEC waiting to be approved by a committee that should have been assembled from the ministry of finance, the ministry of environment, and the ministry of energy and water, in addition to EDL. Although the committee was not formed because the government had resigned, it was agreed to continue with the project (in late 2013, early 2014) and assemble a certain committee to evaluate and manage the four proposals, but the final approval should be given by the new appointed government. It is important to note that the four proposals could be approved at the same time, it is not necessary to choose one only.

Following this, the UNDP studied the wind movements in Lebanon under a project entitled "ATLAS Winds". The study confirmed that Lebanon could benefit from winds of at least 1,500 Megawatts of power. Chafic Abi Said stated that wind farms should be built in regions with extensive wind power such as the Bekaa valley. But for a proper implementation of the concept, the wind power must be observed for at least two straight years since the wind

direction and efficiency can change from year to year. Wind ATLAS calculations should be based on several years of wind testing since basing the analysis over one year can be misguiding. The Wind ATLAS project was not as effective as it was intended for it to be. In contrast, some of the Lebanese people in the private sector were encouraged by this initiative and launched the "Hawa Akkar" project (Akkar's wind/air) that studies extensively the wind power generation.

Also, Hassan Harajli forecasts that any wind farm that will be proposed in the near future under the form of a Power Purchase Agreement (PPA) for the next 20 years, will set the cost of each Kilowatt-hour starting 11 US cents up to 14 US cents (depending on the origin of the machines to be used; China, Europe, etc.). Consequently, the price is less than the half of what Lebanon currently pays for each Kilowatt-hour. It is important to mention that the pricing includes the Lebanese risk factor since Lebanon is considered a politically unstable country. In other words, the private sector always tend to increase its Internal Rate of Return (IRR) and therefore increases the prices when extra risk exists (for example, in Europe this price will fall to 9 US cents as a maximum because of the risk factor elimination). Moreover, when electricity is produced on a large scale, the cost of a Kilowatt-hour will decrease following the economies of scale.

4.4.3.2. Solar Power

The ministry of energy and water proposed the "Beirut River Solar Snake" that aims at providing 1 Megawatt of power through solar panels by the mid of year 2015, as per Joseph Al Assaad. The goal is to achieve 10 Megawatts at later stages. The ministry has the required budget, and the project contract was signed with a private corporation. Same as the wind farms, the solar farms projects will include the private sector, with each farm delivering between 100 and 200 Megawatts. In the same context, Lebanon can for instance make use the commercial buildings rooftop spaces to implement the PV technology. For example, "ABC" or "Spinneys" which are commercial malls, can be beneficial in this matter. These malls can produce their daily electrical needs using solar panels. The technology can also be implemented on private buildings, where a new design codes for the new buildings to allow such PV implementation for each residential unit should be implemented. PV panels are an

excellent way to shave off some of the electricity needs and might be able to supply full power in rural environments.

Many theories regarding land spaces in Lebanon confirm that our country is limited in terms of empty lands that could be used for the renewable energy sources' implementation. However, the UNDP stated that in Lebanon, we don't have a land space problem. To confirm this statement, Hassan Harajli conducted a study under the renewable energy strategy, and found that when dismissing the agricultural lands, the urban areas, the forests, and the reserves, the amount of land spaces remaining is more than enough/needed/, and in fact it exceeds Lebanon's ability to "plant" solar and/or wind farms. For example, Lebanon has the Hermel valley which is perfect for the renewables' implementation, also, the photovoltaic (solar power generation) possibilities are endless.

Moreover, a couple of Lebanese private companies working with the renewable energy implementations and energy efficiencies, have launched a new solar power generation system delivering electricity starting with 10 Amperes of power supply, up to 25 Amperes (10, 15, 20 and 25 Amperes), as per Lara Chalekian and Fares Abi Dargham. This proposal is aimed for several emplacements including homes. The solar power panels are similar in shape to the solar water heaters but require more space. For example, a 10 Amperes system cost around 10,000 USD including the machines, setup, and implementation, whereas a 20 Amperes system cost around 15,000 USD. It may seem as a bulk but today most of the banks are offering zero-interest loans for that matter (the green loan) with the support of the LCEC and the Lebanese Central Bank operation under Banque Du Liban (BDL). So after three years, people will get return on investment since they by then they would have paid all the sum, in contrast to the private generators' bills which should be paid for life. If we consider the loan for green energy, people would be paying less than the amount they pay for the private generators per month. And the most important thing is the eco-friendly green electricity provided by this system compared to the traditional systems. The only setback is the space needed, hence the concentration is on villas or private home properties since the 20 Amperes implementation requires around 20 square meters.

The goal is to substitute the power delivered by the private generators that people pay for each month, therefore each home would have its own private eco-friendly green power delivery system. This concept is divided into two sections: off-grid and on-grid. The former includes batteries while the latter includes the "net metering" which is proposed by EDL, as per Rani El Achkar. The net metering concept is when consumers generate energy though solar panels and don't use it, they can sold it to EDL and therefore decrease their bill amount; it's a credit/debit system.

4.4.3.3 Hydro Power

Concerning the hydro power in Lebanon, there are several projects that include the rehabilitation of the current existing plants, a possible addition to those plants, and new dam constructions plans that have the ability of supporting hydro power plants. Hassan Harajli said that Lebanon now has 4% of hydro power in terms of renewable energy, and the maximum attainable figure is 8%. For example, in Reshmaya there are three turbines out of which only one is operational and the fact that the other two should be maintained is incorporated in the Bassil 2010's action plan concerning the hydro improvements section since most of the hydro plants were constructed in the 1920s and operate a t low efficiencies. Furthermore, a French company has studied these project in Lebanon, and found that the Lebanese government can easily restore the hydro plants while doubling their capacity and resulting in excellent economic returns; i.e. low maintenance costs and low environmental impact.

4.4.3.4 Biofuels and Biomass

The biofuels are fuels are made by a biomass conversion (living organisms, most often referring to plants or plant-derived materials). This conversion can result in fuel in solid, liquid, or gas form. Biofuels have increased in popularity because of rising oil prices and the need for energy security, in addition to being environmental friendly energy sources. Although they are very expensive, they have the advantage over other sources because of their ability to operate in the existing power plants, hence there is no need to build new plants for them. Biofuels are similar to traditional fuels with less carbon emissions after burning. For example, we can deploy biofuels in the Zouk plant and it will work immediately. These

energy sources are processed from waste and animal fats. The first form is the biogas or "Syngas" which can used in multiple areas. An additional advantage is that the residuals of the process can be buried underground with no additional harm to the environment.

Georges Abboud described that biomass conversion could make a lot of sense in Lebanon, where exist mountains of garbage such as Bourj Hammoud and Nahmeh. There is already a strategy that has been put in place in Lebanon, and consists mainly of the forest management where the biggest potential concerning biomass exists. Biomass is a part of the Lebanese national plan for solid waste management (Solid Waste Management Plan) executed by the ministry of environment. CEDRO-UNDP started to study this topic in 2010 under the "Biomass strategy for Lebanon" which describes the different flows of biomass. But still, this strategy has not been adopted for Lebanon.

An earlier suggested solution was the Burj Hammoud initiative where two private companies proposed a nine million USD project to extract "methane" gas from the existing dumps after being buried underground for a certain period of time, as per Chafic Abi Said. For example, after 15 years of burying the waste, the methane gas is produced which could be deployed to generate "clean" electricity. Experts, along with the private companies, calculated the amount of the expected generated electricity in order to forecast the project's profits. "Global Energy Facility" (GEF), which operates under the World Bank (for environmental financing) offered three million USD as a part of the nine million USD investment. The forecasted electricity generation would be sold for three million USD, and the rest of the amount was to be financed by the Lebanese government. In addition, the machines that were supposed to be used for the electricity generation were also planned for be used in other power plants. With all these advantages, the project was not initialized and failed since there is no regulatory body that directs and manages the solid waste in Lebanon.

4.4.3.5 Decisions

Concerning the decisions, Chafic Abi Said stated that it is crucial for the Lebanese government to stand up and decide to solely deploy the natural gas or liquid gas for power generation. A firm decision should be taken since this source is a clean one, which aims at

protecting the environment. The interviewee added that the critical factor is the strategy, which should be positioned above all in order to define the roles and responsibilities of each of the public sector and the private sector since each one alone cannot operate successfully. In addition, connecting all the electricity grids aiming at solidifying and stabilizing the electricity network is a critical step. This process has also the advantage of minimizing the losses after facing problems in the grid; such as storms, etc.

4.4.4 Additional Discussion

4.4.4.1 Natural Gas

The Lebanese people should be optimistic concerning the extraction of natural gas because it is a "game changer". Today, we use heavy fuel oil and diesel oil which Hassan Harajli described as being the dumbest most expensive power generators in the world. In addition, the Lebanese government financially supports the electricity sector by paying around two billion USD each year, which is a huge waste of money that can invested in renewable energy. For instance, Jordan, who also deployed the heavy fuel oil and the diesel oil, is now implementing the renewable energy left, right and center with power up to 100 Megawatts. This shows that when there is a true will and cohesion between the authorities, successful results are achieved.

The fact that extracting natural gas from our Lebanese land is a game changer and a big time favorite, is because of two factors; first of all, it is important to mention that the Lebanese power plants were constructed to run on natural gas, instead Lebanon is deploying heavy fuel oil and diesel oil. The results are higher costs, less efficiency, and increased pollution through augmented carbon emissions compared to natural gas. The latter is much cheaper than heavy fuel oil, and is half as polluting as in greenhouse gas emissions. In addition, it would be a Lebanese resource which could be "sold" or "exported", hence gain profits which in its turn can be reinvested in the renewable energy field. Second, natural gas can run up and run down. In other words, for example at night, people need electricity more than the day, hence, the natural gas generators will produce more power, therefore following the load. Also, natural gas runs side-to-side with the renewables making it very quick to responding to the constantly growing energy demand.

4.4.4.2 Renewables and Efficiency

Investment in renewables is a "capital investment" where money is paid only at first for the plants' construction, as per Nader Shahadeh. Conversely, traditional fossil fuels power plants need constant maintenance, hence, running costs should always be paid. In contrast, biogas needs running costs because it is bought, but no huge investments need to be paid at first stages.

Hassan Harajli added that renewable energy sources are not "golden bullets". Meaning that for the solar power generation, the drawback is the fact that the sun doesn't shine at night. As for the wind power, if we add up the total of power delivered over a year, we find that only around 35% of the power is being supplied. Hence, there is no escape from using the conventional existing power generation methods that the world is currently using in the near term. Nevertheless, on the long term, the world can totally become independent from fossil fuels.

The traditional power generation system is so simple; it is designed with a big power plant, transmission lines, a low-voltage distribution, and an end user. When the end-user needs more power, the generators will produce more power. Therefore, if we have a thousand of the renewable energy generators spread across a country, divided into solar plants placed on buildings, solar farms, wind farms, hydro power, etc. then a utility operator wanting to manage these systems and keeping a load of 24/7 electricity is a colossal challenge. The solution is to turn to smart systems called "smart active systems", which are considered a new technology. In fact, several research have already started around the world in order to learn how to manage these smart active systems. In other words, the concept follows the demand-side management perception; for example, an agreement is made with a certain power plant to deliver power once there is an excess in energy demand that renewables cannot satisfy (in exchange for fees).

On the other hand, a 20% bar of renewables' energy supply can be easily managed, but when the bar exceed 20%, then rethinking the management of the renewables system should be induced. Lebanon has a target of 12% renewable energy by year 2020, and 20% by year 2030. This percentage is a realistic objective for Lebanon; the easiest part is to place the first 10% of

renewable energy, the next 10% are harder, and the next 10% are harder and harder, and so on. The Lebanese target is 5,000 Megawatts where the first step is 2,400 Megawatts, with hydro power generation supplying up to 280 Megawatts, and with only one wind farm, Lebanon can reach the 5,000 Megawatts figure easily. After that, it starts to get more challenging since the best sites are taken first for their security, reliability, and efficiency in renewable energy generation. For example, concerning wind farms, there are three classes following the wind speed; class "A", "B", and "C", with "A" being the most effective. In Lebanon, class "A" fields will be turned into wind farms, then moving to "B" is due to later stages. Class "C" can still be economically viable, even in Lebanon. The same concept applies for hydro power generation.

Nader Shahadeh affirmed that reaching a 100% renewable energy supply in any country of the world is not easy to achieve; shifting from well-known mature technologies to renewables needs time. Countries around the world are trying scientifically to produce more efficient power plants, relying on natural gas which is a clean energy source, but the worldwide concern is not just about the environment, it involves the scarcity of the oil which is controlled by Iran. Venezuela, Saudi Arabia, etc.

The developing technologies are now more into renewable energy sources so to release the fossil fuels at later stages. Most of the new power plants that are being constructed around the world rely on natural gas, and some relying on nuclear which is no totally environmentally friendly but is considered better than fossil fuels. Hence, the "Energy Security" requires a "Distributed Generation" of the energy sources, i.e. a combination of both the fossil fuels and renewable energy sources in order to provide power, at least in the short term. Step by step, the world needs to shift completely to the renewable sources. The best scenario is one where Lebanon can produce its electricity from renewables and then use any discovered oil and gas resources towards exporting them to obtain needed cash to settle its national debt. However, and until we get to that point, Lebanon should make sure that every effort is made to tap all available sources of renewable energy before resorting to any other options.

4.4.4.3 The Private Sector

Chafic Abi Said described that in order to open up on the renewables topic, Lebanon needs to include the private sector in the equation. In order to do so, a law amendment is needed, which in fact do exist under the code 462 (existing since year 2002), but no one implemented it so far. This requires a "Regulatory body" to study the project in details (as applied for the oil sector). Bassil amended the law concerning this, and transformed the regulatory body into an "advisory unit" where he (or any minister) will have the final say in any decision to be taken.

Including the private sector in the renewable energy initiatives is crucial since first of all, the private sector has a different mentality. Second, it is motivated by the profits or gains. For instance, placing an employee in the public sector will perform less than placing him in the private sector. Moreover, in Lebanon there is a mismanagement in almost any sector, there is no organization of priorities, and the worst is that politics is involved in every detail. Therefore the privatization of the EDL for instance can be beneficial while keeping the basic propriety for the Lebanese government. Third, the private sector possesses the required knowledge and know-how. Fourth, it has the essential investments. Fifth, it is capable of achieving what the government cannot. Finally, it can behave freely and most importantly without any political intervention.

However, the public sector and/or the government should "clear the way" for the private sector to gain or make profits as a result of its investments. Yet, the profits must be audited or controlled by a politics-free regulatory body assigned by the government.

4.4.4.4 SPS

The Solar Power Satellites (SPS) are huge platforms that can be placed in free space to absorb the solar power, convert it into electricity and redirect it to earth using microwave where it can be fed into the electricity grids and distributed to be used by the consumers. There was a unanimity with the Lebanese experts concerning this topic where they said that this is among the ideas that are still far-fetched at this stage and the economics are far from being worth

it. A proof of concept is always encouraged but "the world usually should go after the low hanging fruits before it goes after the more complex ideas".

The SPS concept is applied today on a small scale where regular satellites "feed" energy from the sun and transform it into power for operational use. But as for the large scale, SPS is not applicable nor feasible right now in terms of money, technologies, and implementation. In addition, people who "control" the Space are few countries such as China, Russia, and USA which makes it tighter because of the various political issues, as per Chafic Abi Said. Therefore, if any, SPS is still in its early stages and will not be feasible before 15 to 20 years as per Georges Abboud.

There was an initiative some time ago aiming at planting several huge solar plants in some countries like Chile, Australia, Mexico, and North Africa. As per the studies, this proposal would be enough to supply the whole world's electricity demand. The project didn't work even though it was to be implemented on Earth, consequently SPS will not succeed especially right now where the world is witnessing conflicts and problems between the majorities of the countries, as per Nader Shahadeh.

Additionally, the SPS must have the appropriate infrastructure that can support it, as per Michel Madi. This includes raw materials, like silicon, aluminum, and iron; in addition to manufacturing capabilities for the rockets and engines and finally the know-how to build PV panels. A lot of investment is being undertaken in renewable energy fields that are much nearer to maturity than the SPS technology, as per Ahmad Houri. Of course, Lebanon cannot invest in such a project for it is a long shot. Lebanon should concentrate on more realistic, applicable, and mature technologies. This is because, from the maintenance point of view, there are a wide knowledge and expertise that can help in solving any related issue. As from the prices' point of view, it costs less because it has been existing in the market for a long period. Finally, Lebanon cannot afford to implement immature technologies, hence "safe" technologies are the solution. This is why, today's concentration is on renewable energy sources such as solar, wind and hydro, and not on biomass, biofuels and bioenergy, as per Joseph Al Assaad.

4.4.4.5 DESERTEC

Nader Shahadeh explained that there was a proposal entitled "DESERTEC". It was an initiative from the European Union who stated that it will invest in an electricity project in the North African region. Algeria, Libya, Egypt and Morocco were the target countries in this project where solar farms would be placed in their deserts to collect power and distribute electricity to Lebanon, Syria, Jordan, and the aforementioned countries. There were two applications; either distribute electricity through the sea, or start the implementation in Spain, passing by the Mediterranean Sea through Lebanon and Israel, arriving to Morocco. The latter proposal was not accepted because Lebanon cannot be in a same grid with Israel (same applies for Syria). The Europeans offered their help by building these solar farms, and running them using their experts. They would benefit from this project by delivering electricity not only for them but also for the countries in the Middle East, North Africa, etc. The proposals failed due to political reasons, nevertheless negotiations are still in place.

4.4.4.6 Hydrogen Cells

Chafic Abi Said added that today, a promising technology is the "Hydrogen Cells" or "Fuel Cells" power generation. Although implementations of this technology should have started ten years ago, it is never too late for major breakthroughs. For example, cars or houses could be energy-supplied with only a small Hydrogen-cells battery since Hydrogen possesses a huge heat capacity. The process starts with producing clean Hydrogen from water (H_2O) by separating the H (Hydrogen) from the O (Oxygen) through electrolysis. Then the clean Hydrogen is used to produce clean energy. This technology should be available in the very near future because currently it is still subject to intensive research and development.

4.5 Discussion

The analysis in this thesis shows that fossil fuels do harm the environment for researches and studies proved that CO_2 emissions or greenhouse gas emissions resulting from burning these fuels are a major threat to the environment, yet promote the destruction of planet Earth. Moreover, these same studies have indicated that fossil fuels will deplete over time where in fact the existing reserves will only suffice until the end of the current century. In contrast,

renewable energy sources are the key players in this dilemma since they provide clean energy from different natural sources that do not deplete over time, such as solar, wind, and hydro power. Although these sources should be introduced slowly into the equation of energy as a complementary supply to the current energy delivery methods, they will consequently replace fossil fuels and therefore constitute reliable sources that provide green energy. Awareness, social responsibility and sustainability are developing each day. These elements will be the main constituents in the shift from traditional harming energy sources to clean ever-lasting ones, with the additional benefit of money saving.

4.6 Conclusion

This chapter described the findings of this thesis based on the semi-structured interviews conducted with the Lebanese experts concerning the renewable energy sources and the electricity sector. Also, the analysis was based on the literature review through the secondary data collected. The results constituted a unanimity starting with the literature review and arriving to the Lebanese energy experts.

Chapter 5

Conclusions and Recommendations

5.1 Introduction

In the introduction and methodology chapters, I explained that this was an exploratory research with the aim to explore the perception of the Lebanese experts for the need and importance of the renewable energy in Lebanon, taking into consideration the electricity sector case. This chapter will describe the conclusions and recommendations, and will also define my contributions to this thesis, hence my added value.

5.2 Main Findings Comparison

The findings in this thesis match the main theories and the previous results mentioned in the literature review (Chapter 2); renewable energy sources are needed everywhere around the world and especially in Lebanon. The Lebanese government could benefit from the saved amounts of money by implementing the renewable energy sources and could therefore repay Lebanon's national debt.

My contributions are the conducted semi-structured interviews since they reflect the current status of Lebanon regarding the progress and implementation of the renewable energy sources. Also, I propose a new concept for the currently considered far-fetched SPS. This concept is defined by the construction of the SPS platform in Space from spatial/lunar resources and therefore, eliminate all Earth-lunch costs. To satisfy the latter condition, 3D printing is needed. While being the latest technological trend, 3D printing is now the new era capable of printing 3-dimentional objects using low-cost materials such as sand, glass, powder, etc.

Kramer (2013) stated that in the very near future, 3D printers will be placed on the moon under a lunar base as per NASA and Made In Space Inc. The latter is a private corporation that has successfully tested 3D printing in Zero-G (Zero-Gravity or not experiencing the effects of gravity) and is scheduled to fly a 3D printer into Space in spring 2014. The

objective is to print materials in space. But why not consider 3D printing materials needed for SPS' construction using lunar and asteroidal ore/resources under a Moon base or a Lunar base. The method should be processed in free space since there, the Sun's energy can be captured 24/7, worry-free of the day and night cycles comparing to Earth.

Oxford Dictionary defined 3D printing as *"a process for making a physical object from a three-dimensional digital model, typically by laying down many successive thin layers of a material. It is the making of parts and products using a computer-driven, additive process, one layer at a time"*. In other words, 3D printing can be also defined as a method of creating a three-dimensional compact object of virtually any shape from a digital model. CREATE IT REAL detailed that *"it is achieved using an additive process, where successive layers of material are laid down in different shapes. 3D printing is considered distinct from traditional machining techniques, which mostly rely on the removal of material by methods such as cutting or drilling, known as subtractive processes"*.

5.3 Limitations

I recognize that the sample of the semi-structured interviews is small and as a result the conclusions might be limited. As this is an exploratory research, it is not the outset to make conclusions based on statistical facts but it is the idea to make tentative conclusions that can be used to establish if any further research would be feasible.
Another limitations is the hostility of the Space where asteroids could harm the SPS platform and could maybe destroy parts of it. Further studies need to assess the risk of these incidents taking into considerations the materials used in the platform's implementation.

In addition, the costs of the lunar base or the Moon base are yet to be determined since they require further analysis and initial cost estimations. In this context, Tomas Rousek, a "Jet Propulsion Laboratory" scientist at NASA stated that "*it* (the lunar base) *would have a very good cost-value ratio as you don't need to import as much material from Earth.*" He added that "*since we don't have the necessary transport capacity to the Moon at the moment, estimating a price now would be very inaccurate. As a comparison, the International Space*

Station has so far cost approximately $150 Billion but a lunar base could be designed much more cheaply with private companies."

5.4 Recommendations

We as humans, have an obligation to continuously explore, think of and discover new technologies and solutions to save ourselves, our children and our planet. Saving money now by using polluting energy technologies and letting our children worry about the ramifications does not seem like a wise strategy.

Therefore, the Lebanese case concerning the electricity and renewable energy should be more serious for it has become a critical issue today. I recommend studies concerning green awareness in Lebanon since it is not and has never been in our culture. It should start in the early stages for people (or children) so they can understand the effect of the pollution on the planet, and therefore act as green to protect the environment. The education and the government should stress on the importance of the green strategy. By doing this, the interest in the green conception would grow with the person and hence remains printed in the people's minds. In addition, awareness should be created as much as possible, for instance in universities, courses should be implied on students within their majors such as ecology, renewable energy, etc. All of this is because the renewable energy has a lot of potential and especially in Lebanon. For example in Europe, there no electricity cuts, but still we see huge solar farms that are being deployed for two reasons; first because they want to green and be eco-friendly, second because they are saving money following green implementations.

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Appendix A

Interview Questions

1- Why the Lebanese electricity production in 2013 was not sufficient for Lebanon's electricity needs? We saw the "Fatma Gul" ship delivering power, what do you think the problem was?

2- Do you think that getting power via ships from outside countries is environmental friendly? If yes, please tell me more? If no, please explain why and how do you think this problem should be solved?

3- Do you think that the current methods for producing electricity harm the environment? If yes, how? If no, why?

4- Do you think we need to replace our conventional electricity that is produced from fossil fuels by other sources that could be less damaging to the environment? If yes, what do you propose? If no, why?

5- It is known that the fossil fuels are the most secured sources of energy as in the most reliable ones. This is called the "Energy Security". Do you think that we should undertake the "Distributed Generation" where the energy sources are divided between fossil fuels and renewables? If yes, can you please elaborate? If no, why?

6- The bio-fuels are fuels are made by a biomass conversion (living organisms, most often referring to plants or plant-derived materials). This conversion can result in fuel in solid, liquid, or gas form. Biofuels have increased in popularity because of rising oil prices and the need for energy security. What do you think of this concept? Do you think there's a chance for them to be competitive with fossil fuels and renewables? If yes, please elaborate? If no, why?

7- What do you think about getting electricity and power from the sun?

8- Do you think that the implementation of terrestrial solar panels is sufficient to satisfy our power needs in Lebanon? If yes, how? If no, why?

9- Do you think that the terrestrial solar panels can be limited due to the weather / climate conditions, day and night cycles? If yes, what do you propose? If no, please tell me more.

10- There are proposals of Solar Power Satellites (SPS) which are huge platforms that can be placed in free space to absorb the solar power, convert it into electricity and

redirect it to earth using microwave where it can be fed into the electricity grids and distributed to be used by the consumers. What do you think of this proposal? Do you think it is feasible? If yes, are you with this idea? If no, why?

11- The SPS are considered environmental friendly power delivery platforms compared to the power delivered by fossil fuels which is contributing to the global warming because of the greenhouse gas emissions (CO_2) as per the scientists, what do you think of this? Do you confirm this statement?

12- An important note is that the SPS require huge investments because of their expensive launching costs from earth into space. Do you think it is important that Lebanon and other nations should invest in such projects in order to preserve our nature from the pollution caused by the fossil fuels? If yes, could you please tell me more? If no, why?

13- Do you think that we should stick to our reserves of fossil fuels for now and let our children worry about the energy needs and pollution in the upcoming years? If yes, why? If no, could you please tell me more?

14- Would you like to add anything else?

Interviewees

1- George Abboud, Chief Operating Officer at Earth Technologies
2- Ahmad Houri, Professor at LAU
3- Rani El Achkar, Technical Engineer at LCEC
4- Hassan Harajli, Project Manager at UNDP-CEDRO
5- Joseph Al Assaad, Consultant at LCEC and Professor at USEK
6- Lara Chalekian, Manager at Green Dynamics
7- Nader Shahadeh, Former VP at Lebanese Solar Energy Society (LSES)
8- Michel Madi, Manager at Maintenance Management Group (MMG)
9- Fares Abi Dargham, Manager at Green Power Technology (GPT)
10- Chafic Abi Said, Former President at LSES and Former EDL Consultant

Appendix B

The National Energy Efficiency Action Plan for Lebanon

NEEAP 2011-2015, Approved by the Council of Ministers of Lebanon (on 10 November 2011)

The NEEAP is a clear road map for the development of the renewable energy sources and for the energy efficiency initiatives in Lebanon. This is following the MoEW's and Lebanon's prime objective which is to reach 12% of renewable energy by 2020.

The 14-Initiative Narrative NEEAP are:

Initiative 1: Towards Banning the Import of Incandescent Lamps to Lebanon;

This initiative aims at banning the import of incandescent lamps to Lebanon by the end of the year 2012. This decision can only be reached through the application of different independent but interrelated actions, mainly the 3 million CFL's project.

Initiative 2: Adoption of the Energy Conservation Law and Institutionalization of the Lebanese Center for Energy Conservation (LCEC) as the National Energy Agency for Lebanon;

This initiative aims at the adoption of an energy conservation law for Lebanon, including the institutionalization of the Lebanese Center for Energy Conservation (LCEC) as the national energy agency for Lebanon. The law offers a legal framework for the following subjects: energy audits, energy efficiency standards and labels, financial incentives for energy efficiency appliances, and net-metering and the LCEC's national role.

Initiative 3: Promotion of Decentralized Power Generation by PV and Wind Applications in the Residential and Commercial Sectors;

This initiative aims to support the residential and commercial uses of wind energy and solar photovoltaic systems by increasing decentralized power generation by renewable energy sources with a target to achieve an installed capacity of 50 to 100 MW by 2015. This requires technical, marketing, as well as financial support with necessary actions to be taken at the legal framework.

Initiative 4: Solar Water Heaters for Buildings and Institutions;

This initiative aims at promoting the use of solar water heaters mainly in the residential sector with the aim to facilitate the installation of 190,000 m^2 of solar collectors by 2014. This can be achieved through different actions including proper financial and technical schemes.

Initiative 5: Design and Implementation of a National Strategy for Efficient and Economic Public Street Lighting in Lebanon;

This initiative aims at the design and implementation of a national strategy for public street lighting in Lebanon in order to offer a safe and energy efficient street lighting with an intelligent monitoring, control, and maintenance procedure. This initiative can be achieved by updating, replacing, and installing new photo-sensor devices in the different street lighting sectors in order to illuminate the roads when needed, and to develop technical specifications for the energy efficient street lighting lamps, as well as the increase in the know-how and capacity of the personnel working on the operation and maintenance.

Initiative 6: Electricity Generation from Wind Power;

This initiative aims to promote the generation of electricity through the use of wind energy. This can only be achieved through technical and policy related actions.

Initiative 7: Electricity Generation from Solar Energy;

This initiative aims to start the development and promote the generation of electricity through the execution of Photovoltaic (PV) and Concentrated Solar Power (CSP) farms. For this to be achieved, proper policy and technical actions are to be taken in addition to ensuring the right financial modalities.

Initiative 8: Hydro Power for Electricity Generation;

This initiative aims to encourage and promote the use of hydro power to produce electricity. This is to be achieved through support of hydro and micro- hydro projects and working on better exploitation of water resources.

Initiative 9: Geothermal, Waste to Energy, and Other Technologies;

This initiative aims to help reduce waste and benefit from waste to energy conversion techniques in addition to the geothermal power to produce electricity. This is to be achieved through several actions including finding a solution to solid waste treatment.

Initiative 10: Building Code for Lebanon;

This initiative aims at setting a building energy efficiency code for new buildings and major retrofits in Lebanon. This code defines the minimum acceptable energy performance for buildings by addressing equipment energy efficiency and envelope thermal requirements accordingly with Lebanese climatic conditions.

Initiative 11: Financing Mechanisms and Incentives;

This initiative aims to provide proper financing mechanism in order to promote the use of energy efficiency and renewable energy. This is mainly linked to the collaborative work with the ministry of Finance and the Central Bank of Lebanon.

Initiative 12: Awareness and Capacity Building;

This initiative aims to raise awareness and build the capacity of all stakeholders working in the energy efficiency and renewable energy sectors. It also focuses on analyzing and disseminating good practices, creating skills and experience in energy efficient technologies, as well as strengthening existing ones.

Initiative 13: Paving the Way for Energy Audit and ESCO Business;

This initiative aims to support the development of the Energy Service Companies (ESCOs) working in the energy audit business and provide them with financial, fiscal, and technical incentives to remove barriers and promote energy audit activities.

Initiative 14: Promotion of Energy Efficient Equipment;

This initiative aims to promote the use of energy efficient equipment in households and other commercial buildings. This includes focusing on electrical equipment and establishing a national energy efficiency standard.

Appendix C

The Policy Paper for the Electricity Sector – June 2010 – Gebran Bassil

This policy paper constitutes a global framework for the electric energy sector in Lebanon, and includes ten strategic initiatives that are integrated and correlated to cover the sector's infrastructure, supply/demand, and the legal aspects. The initiatives are developed into identified plans of action with required budget, financing schemes, and timeframe. The elimination/delay of any initiative and action will lead to losing the policy objective of rescuing the power sector from the current drastic situation to a new sustainable, reliable, and efficient delivery of electricity. A transitional rescue period of 3 - 4 years is required to achieve the goals of this policy.

This paper remedies most of the problems of the electric energy sector starting by the addition of generating capacity to cover the existing gap, demand forecast and required reserve together with the necessary infrastructure to transmit and distribute the generated energy to consumers throughout the Lebanese service territory in a secure and economical manner. The transmission and distribution infrastructures will be upgraded to cope with the capacity additions and to improve the operability of the system, thus decreasing the technical losses. The policy calls for the establishment of a smart grid using meters with remote disconnects from control centers that will be operated with specialized service providers for the transitional period to modulate consumption and reduce non-technical losses.

On the supply side, the capacity addition shall include conventional energy sources that are the most economical with the least environmental impact mainly the natural gas; and renewable energies such as wind, solar, waste to energy, etc. The infrastructure requirements for the natural gas (LNG terminal, pipeline along the coast, etc.) are included in the policy. On the demand side, the policy aims to develop several demand side management and energy efficiency initiatives (e.g., CFL, SWH, etc.) to curb the load growth and improve the load factor which translates into guaranteed savings for the economy. To help increase the penetration of energy efficient devices, the policy calls for the adoption of standards and labels to promote them. Furthermore, a restructuring of the tariff, leading to a gradual balance in the fiscal budget of EDL, is necessary to both generate needed revenues on the treasury

side and to unload the financial burden on the economy and the consumer side by eliminating the need for private generators and providing reliable 24/24 hour service.

The multitude of the projects included in this policy will require a proper legal framework for a transition phase until a permanent and stable situation for the sector is established. Similarly, the necessary financial, administrative and human resources will be given to EDL to manage the transition phase until the corporatization of EDL is accomplished. All this will be done in collaboration and partnership with the private sector and the donor community to benefit from their vast experiences and resources.

The policy will result in a solid power sector with more than 4000 MW generation capacity in 2014 and 5000 MW after 2015, reliable transmission and distribution networks, and efficient delivery of electricity to cope with the overall socio-economic development of Lebanon. The policy targets a gradual implementation of the initiatives in the short and medium terms totaling 4870 M$ for 4000 MW (Government in Lebanon up to 1550 M$, the private sector contribution of 2320 M$, and the international donor community up to 1000 M$), and an additional amount of 1650 M$ in the long term. The full implementation of all the strategic initiatives in this policy will reduce the total losses from 4.4 Billion $ in 2010 to zero in 2014 where 24/24 hours of service is provided, and the possibility of profit making as of 2015; while it will reach 9.5 Billion $ in 2015 if no action is taken.

This ambitious but realistic policy was prepared after a review of all previous studies, and in collaboration of all concerned parties, whether internal or external, constitutional and political, and aims to be approved consensually by the Council Of Ministers.

Appendix D

3D printing...a BICYCLE

Development engineers at the Aerospace Innovation Center, Chris Turner and Andy Hawkins used a 3D printer to manufacture a bicycle. Totally made from nylon powder, the 3D printed bicycle is as hard as steel and can be used as an alternative to conventional bicycles.

Figure D-1 3D printed bicycle (Source: www.techeblog.com)

The demonstration was shown on BBC News UK in March 2011.